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Railroad Location, Trackwork and Structures

166 Illustrations

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RAILROAD LOCATION
TRESTLES
TRACKWORK
RAILWAY STRUCTURES AND TERMINALS

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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscripts are prepared by persons thoroughly qualified both technically and by experience to write with authority, and in many cases they are regularly employed elsewhere in practical work as experts. The manuscripts are then carefully edited to make them suitable for correspondence instruction. The Instruction Papers are written clearly and in the simplest language possible, so as to make them readily understood by all students. Necessary technical expressions are clearly explained when introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the non-essentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed.

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CONTENTS

NOTE—This volume is made up of a number of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1 In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated

RAILROAD LOCATION

RAILROAD LOCATION—(*Continued*)

TRESTLES

TRESTLES—(*Continued*) *Pages*

TRACKWORK, PART 1

RAILWAY STRUCTURES AND TERMINALS

(*Continued*)

RAILROAD LOCATION

THEORY

1. Economic Considerations.—The economic questions that affect the projection of a railroad, while largely matters of engineering, are generally settled by the projectors of the road. It is usually understood that a proposed railroad is to be built and that the projectors have sufficient financial resources with which to build it. In projecting a given railroad, the main factors to be considered are: (1) the estimated cost of the proposed line in relation to its probable revenue, (2) the estimated cost of operation and maintenance; (3) the financial resources of the owners.

These considerations are determining factors in the construction of almost all railroads, and it is the duty of the locating engineer to harmonize them so as to obtain the best possible results for the money expended in building the road. For example, if the route of the proposed railroad traverses a region that is thinly settled and that will be dependent on the road for development, it is a wise policy to build the road as cheaply as possible, consistently with economy of operation, and to provide for future improvement in location when such improvement will be justified by increasing business On the other hand, if the road is to be built through an old and thickly settled country where traffic will be heavy, the cost of operation and maintenance will probably be the most important consideration In such a case, easy grades and light curves should be used as much as possible, within the limits of permissible cost for construction.

Lastly, the financial resources of the owners or projectors and the amount they are willing to spend in constructing the road will necessarily govern the engineer in projecting the location.

2. The preliminary considerations having been decided, the problems to be solved by the engineer are: (1) the selection of the general route between the two established terminal points; (2) the adaptation of the line in detail to the topographical conditions existing along the route selected.

3. Selection of Route.—The selection of the best from several possible routes is often the most difficult problem to solve; for the future of the road often depends on a wise selection of the route. The engineer should bear in mind that a railroad is a commercial enterprise, and is constructed solely for profit. In comparing the merits of alternative routes, the estimated cost of construction, operation, and maintenance must be determined before the final route of least cost and greatest value can be fixed.

4. Relative Economy.—The relative economy of different routes should be carefully considered. The cost of completion to subgrade is not always a deciding factor. The cost of the operation and maintenance of the road is frequently of more importance than the amount of yardage required to complete the grading. For example, it may be better to select one side of a valley in preference to the other, even if the work is heavier, in order to avoid snow slides (which will increase operating expenses), or because one side is more exposed to the sun than the other and is consequently more quickly freed from snow.

The engineer should be able to form an approximate idea of the comparative cost of different lines from the character of the soil, the amount of bridging, the amount of timber available for use along the line, the proximity of good building stone to the line, the probable cost of right of way, etc. These and other important points should be carefully considered for each line before a decision is made. Familiarity with the relative cost of work is only acquired by experience,

but the young engineer can obtain good results by careful study and observation.

5. Controlling Points.—The line of a proposed railroad must usually pass through or near certain fixed points, which are called **controlling points,** since their positions control the location and direction of the road. These points may be either *natural* or *artificial.*

6. Natural controlling points consist of stream crossings, summits of ridges, valleys, and other natural features of the territory through which the road must necessarily pass in order to come within the limit of permissible cost for construction. Thus, if it should be required to

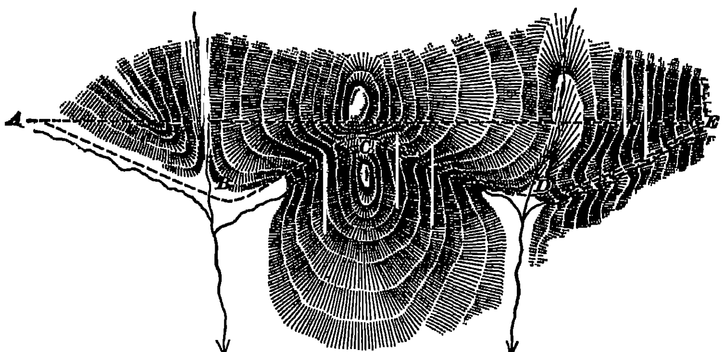

FIG 1

construct a railroad between A and E, Fig. 1, it would be impossible to build the direct line AE at any reasonable cost. The natural route is that which follows the tributary stream from A to the main stream at B and then up the tributary from B to C, thence to D and E, as shown by the crooked line The points B and D are selected with regard to their suitability for the sites of bridges across the two main streams; the lowest point C in the summit of the ridge is given the preference, since the cutting required at that point will be less than would be necessary to allow the line to pass through at any other place on the ridge. For similar reasons, points A and E are selected. The points A, B, C, D. and E are natural controlling points.

7. Artificial controlling points are those determined by the positions of towns, manufacturing sites, industrial plants, etc , through which the road must pass to secure good business, regardless of ordinary engineering considerations. For example, if a railroad has been projected to run from *A* to *B*, Fig. 2, and there are no natural difficulties in the way, the direct route along the straight line *A B* would naturally be selected, because it is shorter and therefore cheaper to build than any other. For business reasons, however, it might be decided to take in the two important towns *C* and *D*, following the route shown by the solid line. Such a route, while longer than the direct line *A B*, will probably be much better to adopt, since the business gained by passing through *C* and *D* may more than compensate for the greater cost of construction and increased operating

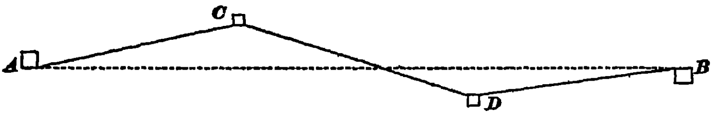

FIG 2

expenses. In such a case, the towns *C* and *D* are artificial controlling points, and the problem for the engineer to solve is to find the best location along the route *A C D B*.

8. Engineering Conditions Affecting Location. The factors with which the engineer has to deal in order to determine the best possible route for a proposed railroad are: (1) *volume of traffic*, (2) *distance*, (3) *rise and fall*, (4) *curvature*, and (5) *maintenance of road.* These will now be considered in order.

9. Volume of Traffic.—Many items of current railroad expenses, such as interest on cost of construction, salaries of officers, and some items in the cost of maintenance are not materially affected by the volume of traffic. Thus, for a given railroad, these items will not be materially greater for a traffic of three trains per day than for a traffic of only two trains per day The operating expenses, however, vary according to the number of trains run, and also according to

the distance run by each train, and are usually computed at so much per train per mile The basis of comparison is therefore the **train-mile**, and the cost of any probable traffic should be estimated on the cost per train-mile

The amount that can profitably be expended in improving the character of the location of a railroad depends on the traffic expected. If a road is projected for light traffic, it is usually best, from an economic standpoint, to use heavy grades and sharp curves in order to make the construction cost as low as possible. If, however, a heavy traffic is expected, a line involving a much greater cost for construction, but having light grades and easy curves, will usually be preferable.

10. Distance.—The effect of distance on the operating expenses of a railroad varies usually according to the number of train-miles. Differences in distance not exceeding 2 or 3 miles in a road or a division whose length is from 75 to 100 miles do not materially affect train wages or track force. Greater differences, however, affect both train wages and track force, and must be taken into consideration when comparing alternative lines

11. Rise and Fall.—The effect on cost of operation of light gradients or small undulations in the grade line of a railroad is comparatively small. A line with light undulating gradients is generally preferable to one with long stretches of grade in one direction. When a range of mountains is to be crossed, in which there is considerable difference of elevation between the foot and the summit, it is usually advisable to select a route in which the climb is concentrated in a comparatively short stretch of heavy gradient, in preference to one where the ascent is distributed over a long distance On the heavy gradients, pusher or assistant engines may be used to take heavy trains over the summit In this way, by using the same motive power, except at the steepest grades, longer trains can be hauled over the whole line than could be hauled on a line with easier but longer grades. The Great Northern Railroad

crosses the Rocky Mountains with easier gradients than are used by the Canadian Pacific Railway in crossing the same ranges. The Canadian Pacific Railway, however, has a far better location for operating than has the Great Northern Railroad, since the heavy-grade sections of the latter road are distributed over a distance of 650 miles, while the heavy grades of the former road are concentrated in one division of 125 miles, where assistant engines are used.

12. Curvature.—Curvature has a considerable effect on the cost of operation, as it adds very greatly to the train resistances. The amount of curvature should be made as small and the radii of curves as large as economic and topographical conditions will permit. Usually, a certain rate of curvature is adopted as the maximum permissible, depending on the character of the country. Maximum curves, however, should be employed only where absolutely necessary.

13. Maintenance.—The expense of maintaining the track and roadway may be materially affected by local conditions along the route. A line that crosses a large number of streets or important highways, where overcrossings or undercrossings have to be constructed, or where watchmen must be stationed, will require a considerably greater expense for maintenance than a line that avoids such features. Similarly, a line built near the foot of clay bluffs or on a sliding hillside will be more expensive to maintain than one built on firm, solid material. The character and number of streams to be crossed have also a considerable effect on the cost of maintenance.

14. Towns and Terminals.—Towns, which are always the main sources of traffic, and terminals, which, besides being sources of traffic, are the main points of traffic exchange, are points of vital importance to the road. No expense within the command of the company should be spared in reaching the centers of towns and in providing the best traffic facilities. A small saving in time and a

small increase in comfort will, other things being equal, secure the traffic. Where the new line comes in competition with old and favored lines, no pains that tact or ingenuity can devise should be spared to induce favor and patronage. Ample terminal grounds should be provided at any reasonable cost, as lack of them places the road at a great disadvantage.

RECONNAISSANCE

15. Definition.—Before making a decision as to the relative merits of the possible routes, and before beginning the survey of the line, the engineer should make a careful reconnaissance of the country through which a projected railroad is to pass. A **reconnaissance** is a rapid examination of a belt or strip of country lying between the terminals of a proposed road.

16. Purposes of a Reconnaissance.—The objects of a reconnaissance may be stated to be as follows: (1) to determine the most feasible and economical line between the terminal points; (2) to locate the controlling points, both natural and artificial; (3) to determine the maximum grade and the maximum rate of curvature; (4) to ascertain the kind of material likely to be encountered in the construction of the road, and to determine the effect of the material on the cost of maintenance; (5) to note the resources of the country and its capabilities for future development, and to calculate the probable effect of the building of the road on this development; (6) to obtain a general idea of the approximate cost per mile and of the total cost of the completed road.

17. Use of Maps.—Before undertaking a reconnaissance, the engineer should procure the best available maps of the region under consideration. The United States Geological Survey has issued topographical maps of some parts of the United States. Such maps are sold at a small price by the government, and from them a great deal of valuable and reliable information relating to topographical features can be easily obtained.

18. Instruments.—In addition to suitable maps, the engineer should provide himself with an *aneroid barometer*, a *hand level*, and a *pocket compass*.

Aneroid barometers, if carefully used, are of great value in determining comparative elevations at different points along a route. It is sometimes important to know the difference in altitude between a gap or pass in a mountain range and the valley below, or between two gaps in the same range, and this can be most readily accomplished by means of the aneroid. A description of this instrument is given in *Leveling*.

A hand level is of great value for reconnaissance, and should be freely used. This instrument is useful in determining approximate differences in elevation between visible points that are not readily accessible. By its use the rate of rise or fall in the slope of a stream or of a mountain side can be rapidly determined. The hand level is fully described and the use of it illustrated in *Topographic Surveying*.

A pocket compass is necessary for determining directions, and for getting the bearings of roads, streams, and valleys along the route. It is useful for checking the courses of streams and valleys that are shown on the map, and is frequently of great value in maintaining a given course or direction through wooded country.

19. General Directions.—Having carefully studied the best available maps, and provided a suitable equipment of instruments for the reconnaissance, the engineer should take the field and make a personal examination of the region to be traversed. From a fairly good map, he can get some conception of the direction, length, and location of any streams to be crossed or followed by the line, as well as a general knowledge of the positions of mountains, valleys, or plateaus along the route. For a knowledge of local topographic conditions, however, he must rely on a personal examination, based on information obtained from local guides and by inquiry among the inhabitants. Nothing should be taken for granted, nor too much dependence placed

on local information or reports; the engineer should, as far as practicable, himself observe actual conditions. It must be borne in mind that a reconnaissance should not be confined to a narrow strip of country along a single line. An examination should be made of an area or belt of country wide enough to cover any possible choice of route. The engineer should first determine the position, character, and limiting effect of the natural or artificial controlling points along the route, and afterwards connect such points by the most suitable line.

20. Unfavorable Reports and Misleading Appearances.—The engineer should not be unduly influenced by unfavorable reports concerning the topography of a route or of a locality. It is his business to get the best line, and he should spare no pains to accomplish this end. Almost every locality contains men with decided opinions concerning the merits of one or more routes; but their judgment is very often warped by local interests. The engineer should not allow himself to be discouraged by rocky slopes, swamps, brush, and timber, which at first appear to be formidable obstacles. A rocky valley, giving the appearance of difficult and expensive construction, will often prove, on careful examination, to be the cheapest location obtainable.

21. Keeping Notes.—Comprehensive notes should be made of all topographical features along the route—such as the size and direction of streams, together with their high-water marks; the slope of important waterways that must be crossed; and any other information concerning them that can be secured. Such information as can be obtained regarding the character of the soil, the prevalence of rock, the amount of timber available for construction, the amount of rainfall, etc. should be carefully noted In addition, the engineer should note the probable quantities of excavation, embankment, and bridging per mile; the prospective fuel supply; the possibilities for business; and all other data from which an approximate estimate of the cost of the proposed railroad can be made.

CHARACTER OF ROUTE

22. Classification.—The different kinds of country through which roads are built may be classified as follows: (1) *prairie* or *plateau;* (2) *valley;* (3) *cross-country;* (4) *mountain.* These will be discussed in the order noted.

PRAIRIE ROUTE

23. A prairie line is usually projected on the route that is most direct and contains the most uniform grade between controlling points. A rolling-prairie region is frequently deceptive in appearance, since the long undulations are often steeper than they appear. In such country, it is often difficult to decide on the best line to adopt. The engineer should not accept a line as satisfactory because the gradients and curvature are within the maximum limits, but should satisfy himself that the line cannot be improved. Many bad mistakes in location have been made in prairie country, in which lines were accepted as being good enough without an attempt being made to improve the location.

24. Deceptive Appearances.—In a rolling or a hilly country, the eyesight is easily deceived and seldom gives to

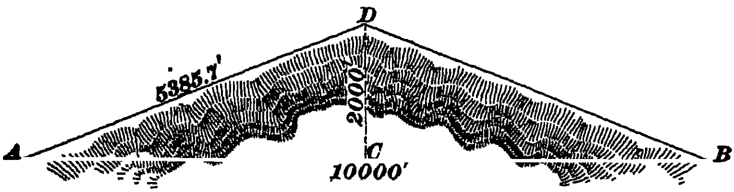

FIG 3

objects their true relative proportions. Such deception can be attributed to two causes; namely:

1. *The eye foreshortens the distance in an air line and exaggerates a lateral offset.*

This fact is illustrated by Fig. 3, in which the points *A* and *B*, 10,000 feet apart, are in an air line between two towns, and the road must cross a ridge, the highest point of which is at *C*; the ridge flattens out at *D*, 2,000 feet from *C*, the

middle point of *A B*. To the inexperienced, the offset *CD*, as seen on the ground, will be greatly exaggerated, appearing to be fully one-half the straight line *A B*, and the conviction will follow that, in passing from *A* to *B* by way of *D*, not only will a great deal of curvature be introduced, but the length of the line will be so greatly increased over that of *A CB* as to make a careful consideration of the route *A D B* out of the question, even though the line *A B* should require steep grades and a heavy cut at *C* This exaggeration is apparent when it is found, by calculation, that the distance from *A* to *B* by way of *D* is only 770.33 feet greater than the direct line between *A* and *B*. This illusion of the eye explains the aversion to swinging the line, too common among engineers, and the undue importance attached to good alinement. The

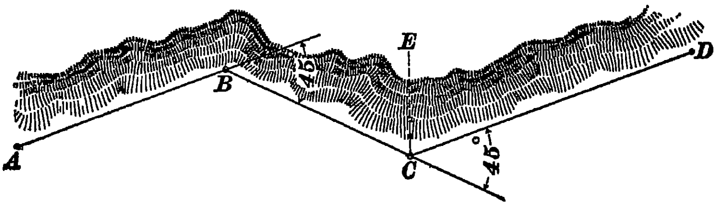

FIG 4

chances are that the line *A D B* is far superior to the line *A CB*, both in cost and grades, while the increase in distance of the line *A D B* over the line *A CB* is less than 8 per cent.

Frequently, a deflection that will not, in reality, add more than 15 per cent. to the length of a line, will appear to double it; and the deplorable mistake is often made of adopting the air line, even though it costs much more than the deflected line would cost.

2. *The eye exaggerates the sharpness of projecting points and spurs and the degree of curvature necessary to pass around them.*

All slopes, when looked at from in front, are exaggerated by the eye Few mountains have slopes exceeding $1\frac{1}{2}$ to 1, or $33\frac{1}{3}°$, yet the eye will estimate such slopes at from 45° to 50°

In running the line *A B C D*, Fig. 4, the engineer, if he were to accept his natural estimate of the angles at *B* and *C*,

would make the angle at C about twice as large as the angle at B, even though he had walked over the line. The reason for this is that, while standing at any point on the line BC, his view of the line CD is cut off by the profile EC of the hill in front, and, in spite of himself, the unseen will be distorted and invariably magnified.

Nowhere is the proverb, "Appearances are deceiving," so true as in an apparently smooth or gently rolling country. The undulations are so gradual that their aggregate is rarely suspected. Abundant experience goes to prove that an air line in such a country is only possible at the cost of heavy grades and long and heavy cuts and fills To avoid them, frequent deflections must be made, introducing curvature in proportion, though the increase in length of line is in no degree proportional to the saving in cost of construction and operation.

VALLEY ROUTE

25. When the route of the proposed railroad is along the valley of a stream, the reconnaissance problem is presented in its simplest form. If the stream is of considerable size, the object of the reconnaissance may be to decide on which side of the stream to run the line. In such a case, both sides of the valley should be carefully examined, and the leading topographic features noted. Unless one side is decidedly better than the other, the determining points affecting the construction and operation of the road should be carefully noted for both sides. Such points are: (1) the relative value of property on the two sides; (2) the number and size of tributary streams, and the probable cost of bridging them; (3) the relative volume of material to be removed; also, the character and cost of handling, and the liability to landslips; (4) the total estimated amount of curvature and the maximum degree of curvature required on either side; (5) the probable business that would be obtained on either side. If these points are carefully considered and the results compared for both banks of the stream, the bank showing the more favorable result is obviously the better route.

If the waterway in question is a small stream, the best line will probably cross it at intervals, in order to reduce the amount of work to a minimum. Where bridging is necessary, the banks of the stream should be examined for suitable locations for abutments and piers.

CROSS-COUNTRY ROUTE

26. Cross-country lines are more frequently used than any other, since most railroads are built across the country to connect terminal points. In a line running across the country, several summits have usually to be surmounted. Here the chief object of the reconnaissance is to determine the gaps or lowest points in the ridges, and the highest banks at stream crossings, in order to reduce to a minimum the total rise and fall, as well as the amount of work required in construction. Most railroad lines of any length combine the characteristics of both valley and cross-country routes. In such a case, the selection of the best line will not only call for judgment and skill, but also entail a considerable amount of hard work.

27. The engineer should bear in mind that, while there is only one best line on any given route, there are always two or more lines from which to make a choice, the problem being to determine which of them is the best. In Fig. 5 is illustrated a case from actual practice bearing on this point The line had followed the river *A B* for several miles, keeping a uniform grade of about 30 feet per mile. It became necessary to leave the river valley and climb a ridge in order to reach a town lying in another valley. The entire country was thickly covered with timber and undergrowth, and consisted of abrupt, irregular hills (called **hog-backs**). The brook *C* was known to the engineer, who endeavored to trace it to its junction with the river, but the brook lost itself in a cedar swamp at *D*, and it was impossible to find the outlet. After repeated attempts to find the outlet, only to encounter each time the ridge *E* that lay between the river and the valley *D C*, he continued the line up the

river, and crossed the latter at B, where a precipitous ledge prevented any further progress along the river. He therefore crossed the neck of land F, and the river at G, and climbed the ridge, doubling about the sharp headland at H; then, swinging backwards, with a heavy fill at M he proceeded with the line KL. Although this seemed to be the only

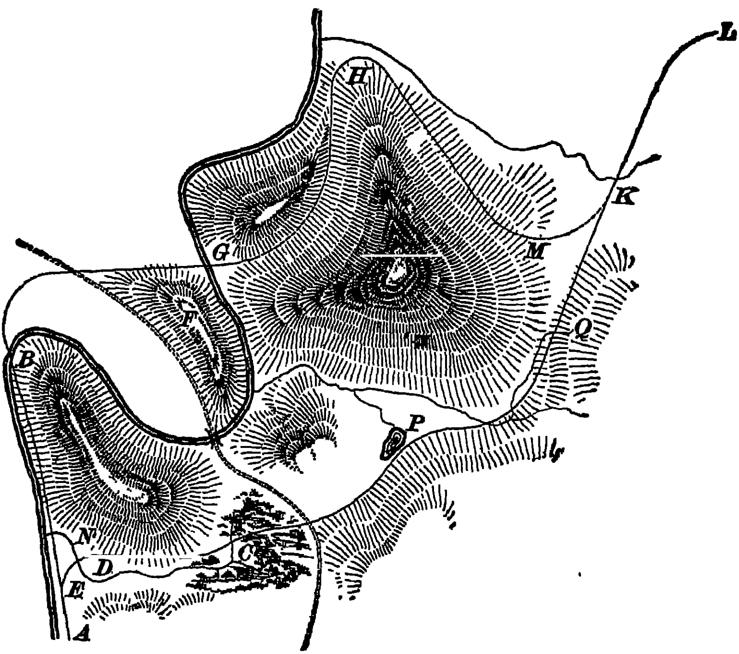

FIG. 5

possible route, it was so rough and crooked that the engineer determined to make another trial. After tramping around for 2 days in a heavy rain storm, he discovered the narrow opening at N through which the brook found its way. He also found the brooks P and Q, and ran a satisfactory line from E to K, with the result that two river bridges and 3 miles in distance were saved, although to get through the ridge at E required a heavy cut

MOUNTAIN ROUTE

28. In a mountainous region, the chief matters to be taken into consideration are usually the lowest crossing points—or **passes,** as they are commonly called—through which to run the line with a minimum cut and grade. Very often, it is impossible to find a direct route through a pass, with gradients that are within permissible limits. Sometimes, the slope of the surface is greater than the adopted maximum grade, and, in order to pass from one side of a divide to the other, it is necessary either to construct a long tunnel or to increase the length of the line to such an extent that the ascent or descent can be made on the required gradient.

29. Development.—When a tunnel is out of the question, or when the expected traffic will not justify the expense of a long tunnel, it is customary to build a surface line of sufficient length to conform to the adopted gradient. Such a process is called **development.** There are several methods of development used for railroad lines; those that are commonly employed may be classified as follows: (1) *surface loop;* (2) *bridge spiral;* (3) *tunnel spiral,* (4) *switch-backs.* These methods will be taken up in order.

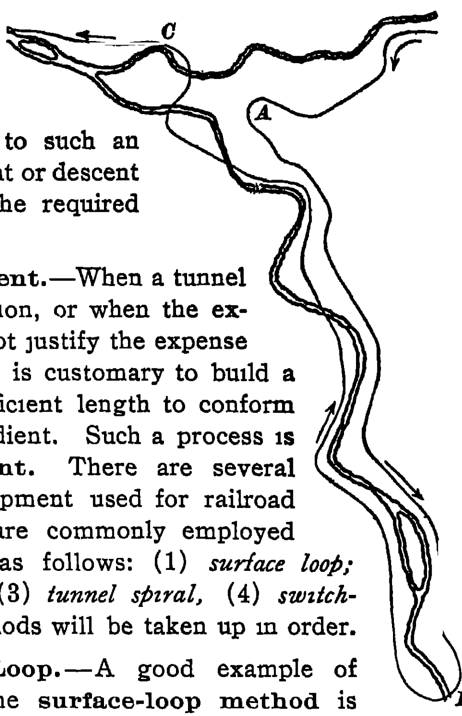

FIG 6

30. Surface Loop.—A good example of development by the **surface-loop method** is illustrated in Fig 6, in which is shown a plat of the Michael Creek loop on a branch of the Canadian Pacific Railway. From A to C, the distance in an air line is less than 2,000 feet, while the difference in elevation is 200 feet. The adopted maximum gradient was 1 foot per hundred·

hence, a direct line from A to C was out of the question, since it would require a gradient of 10 feet per hundred. It was necessary, therefore, to develop the line between A and C in such a manner as to obtain the necessary distance to conform to the maximum gradient. This was accomplished by following the valley of the tributary stream as far as B, where a loop was made, and then returning down stream to the desired point, the entire distance being on the maximum gradient.

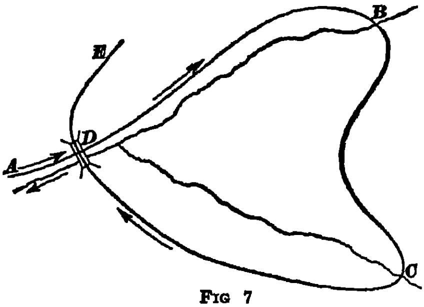

FIG 7

31. Bridge Spiral. Where the topography will permit, the development of a line is sometimes made by means of a **bridge spiral.** In such a case, the line is made to cross itself by means of a bridge or a tunnel, the parts of the line that cross each other being

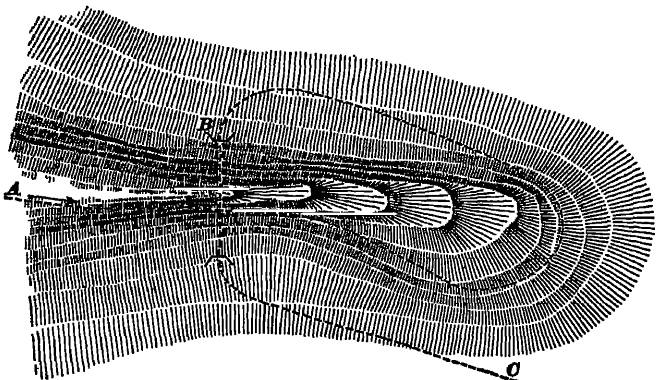

FIG 8

at different elevations. In Fig. 7 is shown a bridge spiral, in which the upper end of the spiral is carried over the lower end on a bridge or viaduct. In ascending from A to E, the line follows the stream to B, where it crosses and continues to C, thence over the tributary stream still ascending, the

line crosses itself on the bridge at *D*, and, on reaching *E*, gains the elevation desired

32. Tunnel Spiral.—In Fig. 8 is shown a **tunnel spiral,** where the line, descending from *A*, forms a spiral whose lower end passes under its upper end through a tunnel at *B*.

33. Switchbacks.—Where precipitous slopes are encountered that will not allow of any other treatment, the required development may be made by the use of **switchbacks.** In this method, the train is switched to a spur track, the switch thrown for another track at a higher elevation, and the train backed over on to this track, the operation being repeated as many times as necessary to reach the desired level. When switchbacks are used, they should be laid out in pairs, somewhat as shown in Fig. 9, in which the train, in ascending from *A* to *D*, passes over the switch *B* to the spur, runs backwards to the switch at *C*, and then goes forwards to *D*.

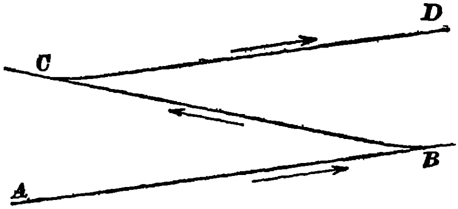

FIG. 9

As already stated, switchbacks are useful for overcoming differences in elevation in a limited space, where other forms of development are impracticable; but they are slow in operation, since two complete stoppages are necessary for passing and repassing switches, and part of the distance between the terminal switches must be run backwards. Switchbacks are seldom used on important railroad lines except as a temporary expedient in cases where it is expected to replace them with a tunnel at some future time.

PRELIMINARY SURVEY

34. Character of the Survey.—The reconnaissance having been completed and a route selected, the next thing is to make a **preliminary survey.** This consists of an instrumental examination of the route for the following purposes: (1) to obtain the necessary information for making a map and a profile of the route, (2) to furnish data from which to project the location; (3) to determine, approximately, the amount of work to be done in the matter of clearing, grading, and bridging, and to furnish data for an approximate estimate of cost of the proposed road; (4) to determine the relative merits of alternative routes that have been examined on the reconnaissance

The preliminary survey may be more or less elaborate, according to local conditions, the degree of accuracy necessary, and the amount of information required. The work should be done as expeditiously as possible, consistently with general accuracy, and should not be delayed for the sake of precision in minor details.

35. Organization of Party.—A complete party for making a preliminary survey through a thinly settled region is usually made up as follows: (1) the *locating engineer*, or *chief of party,* (2) the *transit party*, consisting of a *transitman*, a *head chainman*, a *rear chainman*, a *stakeman*, and one or more *axmen;* (3) the *level party*, consisting of a *leveler*, a *rodman*, and, in wooded country, an *axman;* (4) the *topography party*, consisting of the *topographer* and one or two assistants; (5) the *commissary* and *camp outfit*, which, in a thickly settled region, is seldom required, the party usually boarding at convenient farmhouses along the route.

EQUIPMENT

36. Surveying Instruments and Accessories.—The surveying party should be provided with one engineer's transit, one wye level; two 100-foot tapes of medium steel; two transit poles; one Philadelphia level rod, one hand level; one aneroid barometer; one pocket compass; one hand ax, with extra handles; from two to six axes, with extra handles; two 50-foot metallic tapes; and several pounds of red marking chalk. In a prairie or open country, a supply of stakes should be kept constantly on hand In a wooded country, stakes are preferably cut along the route as the survey progresses.

The steel tape has now almost entirely replaced the old-fashioned heavy link chain. It is well to be provided with an extra tape, and with some one of the numerous appliances for mending tapes. A convenient way of mending a broken tape is to first straighten the ends, if necessary, of the two pieces of the tape; then insert the broken ends until they meet at the middle of a "sleeve" about 2 inches long and of the proper cross-section, lined on the inner side with solder. By pressing a heated iron on the sleeve, the solder fastens the sleeve to the tape.

37. Office Equipment.—A large drawing board, one straightedge, two rubber or celluloid triangles, one horn protractor, one large paper protractor, a pocket case of drawing instruments, a supply of drawing paper, profile paper, pens, ink, erasers, and pencils will constitute a fair office equipment for platting the field work. In addition to these articles, a supply of note books, comprising transit books and level books, should be provided The stationery supplies should be carried in a camp chest or stationery chest made for the purpose

38. Camp Equipment.—When a camp outfit is necessary, the following equipment can be used: three heavy duck or canvas tents, equipped with flies or covers; one wagon and team; one cook stove. with cooking utensils; and a supply of provisions.

The tents should be of good size—preferably 12 ft. × 12 ft., or 12 ft. × 14 ft. in dimensions—and provided with the necessary guy ropes, tent pins, etc. One tent, which is used as an office, contains the stationery chest and drawing board, and is occupied by the chief of party, the transitman, the leveler, and the topographer. Another tent is occupied by the rodman, the chainmen, and the axmen. The third tent is used as a kitchen, and is occupied by the commissary and the cook In the winter season, a fourth tent should be provided to shelter the team.

39. **Medicine Kit.**—When a survey is made through a thinly settled country, the camp outfit should include a small box or chest containing a few simple standard medicines. Such a box, which is called a **medicine kit,** should be proportioned to the size of the party, the climate, and the distance from skilled medical attendance. For surveys of considerable length through a sparsely settled country, a complete assortment of suitable medicines should be provided; but for ordinary railroad surveying, the following medicine kit will be found sufficient for most purposes: one 4-ounce bottle castor oil; one 4-ounce bottle brown mixture, for coughs; one 4-ounce bottle extract Jamaica ginger; one 2-ounce bottle Worburg's tincture, for fevers; one 2-ounce bottle Sun cholera mixture; one 4-ounce bottle Pond's extract; one roll of court plaster, one box cathartic pills; one hundred 2-grain quinine pills; one package soda-mint tablets; one package Dover's powders; one pint bottle of whiskey or brandy. A box or case about 7 inches long, 6 inches wide, and 4 inches deep will be large enough to carry all ordinary medical supplies.

FIELD WORK

40. **Use of Transit or Compass.**—In running the line for a preliminary survey, either the engineer's transit or the surveyor's compass may be used. The engineer's transit is the instrument most commonly employed, although some engineers prefer the surveyor's compass.

A compass is light, easily and quickly set up, and more convenient to carry than a transit; on this account it is preferred for long journeys over rough ground. When the compass is used, the directions of the courses are fixed by their magnetic bearings.

On preliminary survey work, however, the transit is generally given the preference, because it is more accurate and its range of sight is greater than that of the compass. Besides, the transitman can tell at once whether the ground in front is rising or falling, by setting the telescope level and noting where the horizontal hair cuts the rod in the hands of the front chainman. The inclination of a slope can be quickly determined by sighting through the telescope of the transit to a point on the front chainman's rod that is of equal height with the instrument. This operation is often necessary, especially in making a survey to conform to a fixed gradient on a mountain slope or on the slope of a stream.

41. Alinement.—A preliminary survey usually consists of a series of straight lines or tangents connected by angles at the points where changes in direction occur. When a thorough reconnaissance has been made, the preliminary survey should follow more or less closely the line that will be adopted for the final location. In this case, the line should conform as nearly as possible with a surface line that coincides with the adopted gradient; such a line is called a **grade contour.**

In turning angles, they should be taken to the nearest degree, half degree, or quarter degree, to facilitate platting. Abrupt changes in direction, or very sharp angles, which cannot be covered by the maximum curvature, should be avoided, since the preliminary profile in such cases will not be a true guide for the location profile, and is likely to create a false impression of the situation.

42. Chief of Party.—The locating engineer is usually **the chief of party,** and, as such, has general supervision over the party in the field. He selects the route of the

survey, makes arrangements for camp sites or stopping places, and looks after the general progress of the survey. He should take notes of the available quantity and the quality of construction material along the route, select suitable stream crossings, and estimate approximately the sizes of culverts and openings required. He should also keep in close touch with the survey, especially in difficult country and in localities where it is necessary to follow closely a grade contour. In such cases, he keeps just ahead of the party, using a hand level or clinometer when necessary, and selects suitable ground for the line. He fixes the points where angles are to be turned, and from them signals to the transitman. Where the chief of party cannot be seen from the transit on account of the underbrush, he usually signals by shouting, the transitman pointing the instrument in the direction indicated by the sound. This preliminary sighting is checked as soon as the survey has progressed far enough or a sufficient clearing has been made to enable the transitman to see the forward signal. Where the line is not on suitable ground, the chief of party either makes an offset to the required place and continues the survey, or orders the party to go back to a suitable point and start a new line.

The chief of party should keep on friendly terms with landowners and residents along the route, and endeavor to obtain their good will for the proposed road. He should see that property is not injured unnecessarily by the members of the party, and should settle damages caused by the survey passing through cultivated fields.

43. Transitman.—Next in authority to the locating engineer is the **transitman**, who takes charge of the party in the absence of the chief The transitman runs the transit and directs the operations of the transit party. He gives line to the front chainman at each setting of the transit rod, either for a station stake or for a guide to the axmen when there is clearing to be done. He measures and records the angle at each change of direction, and reads and records the bearing of each course. He should keep his instrument

in adjustment, and, on survey, make full and complete notes of the work done by the transit party.

The transit notes should be kept in a regular transit book, and should be plain, distinct, and easily understood. On the left-hand page are entered, in successive columns, the number of the station, the deflection angle, the magnetic course, the calculated course, and the distance between angle points, respectively. The right-hand page is ruled into small squares, for convenience in sketching topography; while in the middle of the page is a vertical red line representing the line of the survey. Station numbers are recorded from the bottom upwards on alternate horizontal lines, the stations themselves

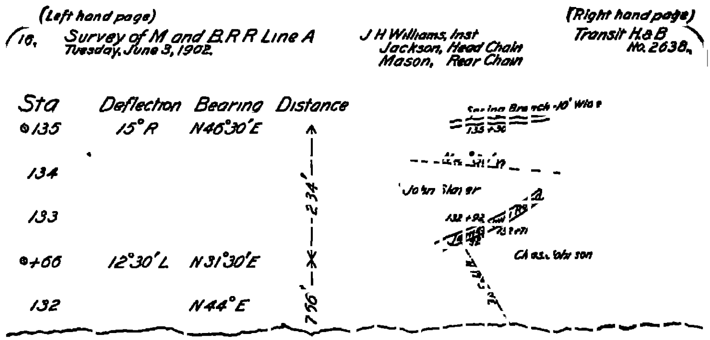

FIG 10

being designated, at corresponding intervals, by dots on the red line on the right-hand page.

The notes should show the bearings and the names of the highways and streams intersected, their widths, and the distances from their intersections with the line to the nearest station of the survey. Property and land lines should also be shown, as well as the names of property owners when obtainable. Bearings should be taken with the transit, and distances to important land corners should be measured along land lines and recorded The first and the last station in each day's run, together with the date and the name of the transitman and the names of the members of the transit party, should be noted.

In Fig. 10 is shown a good form of transit notes of a preliminary survey. The topography is drawn approximately to scale on the right-hand page of the notebook. The pluses—or the distances from the next preceding station to the intersection of the survey with land lines and with both sides of streams and highways—are written in figures expressing feet, as shown.

44. **Head Chainman.**—In running the line, the **head, or front, chainman** carries in one hand a transit rod, and holds in the other hand the front end of the tape or chain. When the tape is out and the front chainman is ready to set a stake, he faces the transit, holding the rod in a vertical position and the chain horizontal, with the end of the handle against the side of the transit rod, and midway between the front and back faces of the rod. He sets the rod in line, moving it to the right or the left according to signals from the transitman or the rear chainman, until it is in the required position In measuring down a slope, he should "break chain," as explained in *Chain Surveying*. At each short measurement with the broken chain, the head chainman keeps the chain horizontal with one hand, while with the other he holds the rod at the proper place between the thumb and forefinger, in such a manner that the rod will swing freely with its foot just clear of the ground. The rod is then allowed to drop vertically to the ground, and the front chainman makes a mark on the ground where the foot of the rod strikes the surface; this serves as a point for the rear chainman to hold the chain for measuring the next section. This process is repeated until the full measurement is made. Another method of plumbing down the end of the chain is for each chainman to carry a plumb-bob, with about 8 feet of line attached to it. A light iron plumb-bob may be bought for about 5 cents, and several of them should be in the surveying outfit.

A stake is usually driven at the end of each tape length to designate the station, and as soon as each station point is determined the front chainman directs the stakeman where to drive the stake, and also calls out the number to the rear

chainman, who has previously called out the number of the station at his end of the chain.

In wooded or brushy country, where clearing is necessary, the front chainman, after advancing to the limit of the clearing and getting the line from the transitman, presses the point of his rod into the ground, causing the rod to stand in a vertical position on line. He then either goes ahead to where the axmen are clearing, and directs their work, or keeps the rod well up with the clearing, getting line from the transitman from time to time.

After locating the position of a stake, the head chainman advances to the next station. This process is repeated until he reaches the point designated by the chief of party for a change of direction. If this point is on rocky or sloping ground, or is near an obstruction, the head chainman selects the best place to set up the instrument, taking the plus at a whole foot on the tape for convenience, being careful in selecting the point to provide for an unobstructed view ahead. As soon as the point is located, he signals to the transitman, who takes up his instrument and walks over to the point. While the transitman is coming up, the head chainman ranges out the line in the new direction and starts the axmen to clearing If there is no clearing to be done, he measures the distance from the transit point to the next station and sets the rod approximately in line before the transitman comes up. The head chainman is next in importance on the transit party to the transitman, and much of the progress of the party depends on his work.

45. Rear Chainman.—The **rear chainman** attends to the rear end of the chain, holding the end of the chain at the last stake set for a full chain measurement, and cutting off the plus to each intermediate measurement. As the front chainman advances, the rear chainman calls out "chain" in time for the front chainman to stop as the rear end of the chain reaches the stake. The rear chainman, after noting that the chain is straight and free from kinks, holds the end of it against the station stake, which he must be careful not

to disturb. As each new station is set, he calls out the number of the station at his end of the chain.

The rear chainman notes the plus to each road, fence, stream, or land line, and records this information in a notebook carried for this purpose. He is responsible for the correctness of fractional measurements, and should be careful not to mistake the 40-foot tag for the 60-foot tag, or make similar errors in reading the tape. In measuring up a slope, he should assist the front chainman to break the tape by holding his end of the length or section of tape high enough above the point to make the tape horizontal. In making such measurements, the rear chainman stands to one side of the line, and holds the required place in the tape directly over the point, using a plumb-bob, as previously described.

In all measurements along the line, the rear chainman should keep to one side of the line so as to avoid obstructing the line of sight between the transit and the front chainman The rear chainman should accustom himself to pacing the distance between successive stations, so as to be able to determine approximately the position of each new stake, and thus save time looking for it, especially if it is hidden in high grass, weeds, etc.

46. Stakeman.—The **stakeman** prepares and marks the stakes and drives them at points indicated by the head chainman. He should keep on hand a supply of stakes, marked and ready to drive. If stakes are not provided, he makes them from suitable material along the line The stakeman may carry his supply of stakes loose, or in a bag or basket of convenient size, or else tied in a bundle with a suitable strap. When the head chainman gets line for a station and marks it, the stakeman should drive the proper stake immediately, and proceed to the next station so as to be ready to drive the next stake as soon as the head chainman gets line with his rod. When there is much heavy clearing to be done, the stakeman should leave his stakes at the last station set and go ahead with the axmen to assist in clearing.

47. Axmen.—The number of **axmen** will vary according to the amount of clearing required. Their duties consist in clearing away the saplings, underbrush, and overhanging branches that would interfere with the sight of the transitman or the leveler. They should not waste time by making a clearing unnecessarily wide; on a preliminary survey, no trees over $3\frac{1}{2}$ or 4 inches in diameter should be cut. If the line passes through a tree of larger size than this, the tree is blazed front and rear, and the line is carried around it by perpendicular offsets or by an equilateral triangle

48. Signals.—In making a railroad survey, it is customary for the transitman and the head chainman to communicate with each other by means of signals. The signals should be plainly given, and each signal should have a meaning that will be unmistakable.

The following are the usual signals made by the transitman to the front chainman: Moving the hand horizontally to one side means that the rod is to be moved in a corresponding direction Moving the hand vertically up or down means that the rod is to be raised or lowered correspondingly. Holding the arm straight up and inclining the extended hand to one side or the other signifies that the rod is to be plumbed by moving its top in the direction indicated. Moving both hands up and down at the same time, or whirling a handkerchief around above the head, signifies "all right" At long distances, the signals can be made plainer by holding a handkerchief in the hand when making them. If the ground is covered with snow, a colored handkerchief should be used for signaling.

When the head chainman signals to the transitman, he usually makes the signals as follows: When line is wanted, the rod is held in a vertical position and moved slowly from side to side. When line is wanted for a turning point or hub, the rod is held in a horizontal position by the front chainman, who moves it up and down once or twice. In signaling for the transitman to move up, the head chainman makes the "all-right" signal described for the transitman.

49. Stakes.—The stakes used for designating the stations should be of uniform size, suitably marked, and firmly driven. They should be made preferably of some light smooth-grained wood that can be easily marked. In a prairie country, where timber is scarce, sawed stakes are commonly employed; they are usually made $1\frac{1}{2}$ inches thick, 2 inches wide, and 24 inches long. In a wooded region, station stakes are usually made from saplings or branches of suitable size—preferably from $1\frac{1}{2}$ to 2 inches in diameter, and from 20 to 24 inches in length—and are called **round stakes.** A good form for a round stake is illustrated in Fig. 11, which also shows the manner of blazing for marking and of pointing for driving. The numbers on the stakes should be marked with crayon, with the number reading

Fig 11

from the top downwards, as shown in the figure. Each stake should be driven vertical, with the numbered side facing the transit.

50. The Leveler.—The level party follows the transit party as closely as possible. The levels of the proposed line and the line with which it is to connect should be referred to the same datum plane, so as to secure a continuous profile, especially if the levels of the established line are referred to the sea level. If such a base is not practicable, an elevation for the starting point must be assumed of such a height as will bring all elevations of the proposed line above the assumed datum plane.

In case the country is wooded, with the added hindrance of thick underbrush, the transit party will of necessity move slowly, and the level party will consequently have much spare time. The members should provide themselves with profile paper and keep the profile platted as the work progresses.

In running a grade line, it is often necessary to have the level up with or even ahead of the transit, in order to

determine whether the ground is above or below grade, and, if so, how far to shift the line to reach the desired elevation.

The leveler is responsible for the correct elevation of the ground at all stations and at abrupt changes of elevation in the surface between stations. He should determine the elevation of the water surface and bottom of channel in all streams crossed by the line, and, when possible, should get the elevation of high water on all important streams.

51. The level rod commonly used on a railroad survey is the Philadelphia rod, which is used as a self-reading rod where elevations are taken to the nearest tenth of a foot; at turning points and bench marks, the target is used, and readings are taken to the nearest hundredth of a foot. In some cases, the Philadelphia rod is used without a target, the leveler estimating the nearest hundredth by the eye when taking a reading on a turning point or bench mark. On a preliminary survey, bench marks are usually placed at intervals of from 1,500 to 2,000 feet, and are located at convenient places near the line, where they can be readily seen by the leveler without much clearing.

52. In a rough broken country, the leveler should carry a hand level for use in determining the depths of ravines or gullies crossed by the line. He first takes a reading at the top of the nearer bank, and then sends the rodman across the ravine to establish a bench mark or a turning point on the farther bank. This being done, the leveler, by using his hand level, rapidly levels down to the bottom of the ravine and up to the peg on the farther side. Sometimes, it is only necessary to determine the elevation of the bottom, in which case the levels are not carried up on the farther side.

53. The leveler on a railroad survey should be quick and accurate He should keep his notes worked up in the field so as to be able to tell, without delay, the elevation of any given station when called on by the chief of party. In running levels on a preliminary survey, time should not be wasted on small details, but care must be taken to insure the general accuracy of the work. For example, a difference of

a few tenths of a foot in the surface elevation is not important, while an error in reading the rod on a turning point or a bench mark might cause serious results. The progress of the entire survey party is largely dependent on the speed of the leveler.

54. Rodman.—The **rodman** holds the level rod at each station and at intermediate points whose elevations are required. He should call out the number of each station as he reaches it, and should be on the lookout for mistakes in numbering the station stakes Should a mistake in the station numbering be discovered, the leveler notes it in his level book and carries the correct numbering forwards until the transit party is notified and the mistake corrected. The rodman should note all important changes in the ground, and, where necessary, give a rod reading to the leveler, pacing the distance from the station stake to the place where the rod is held, and calling out the plus in each instance. At streams, he gives one reading at the top of the bank, one at the water's edge on each side, and one at the bottom of the channel. Where the stream is too deep for the leveler to read the rod when held on the bottom, the rodman ascertains the depth with his rod and calls out his measurement to the leveler. This depth, when added to the rod reading for the water surface, will give the rod reading for the bottom. The rodman should be on the lookout for high-water marks at all stream crossings, and should give rod readings at all such marks when they are found. He should carry a notebook in which should be kept a record of the rod readings at turning points and bench marks In each case, he should compute the elevation and height of instrument as a check on the calculations of the leveler. The rodman should hold the rod vertical for each reading, and at bench marks and turning points he should wave the rod gently to and from the instrument to enable the leveler to determine the exact point of verticality in reading the rod by noting when the center of the target is at the highest point.

55. The rodman should be quick and active. He should exercise good judgment in selecting places for turning points and bench marks, so as to afford an unobstructed view for the foresight and backsight. He should accustom himself to pacing the distance between successive station stakes in order to quickly determine the plus to an intermediate point where a rod reading is to be given, and also to facilitate the finding of station stakes in tall grass or weeds.

56. For a turning point, some firm object, such as a projection or point of a rock, or the root of a tree, or a stump, may be used on which to hold the rod A peg is commonly employed for a turning point, the top of it being cut square and smooth, and allowed to project a little above the surface of the ground; the rod is placed on top of the peg, which should be driven until it is firm and solid, and the top marked with red chalk in order to render it conspicuous in case it becomes necessary to return to it.

The rodman should carry a hand ax or hatchet for use in making bench marks, for making and driving turning pegs, and for light clearing. In rough or thickly wooded country, an axman should accompany the level party. His duties consist in clearing away brush and other obstructions to the view of the leveler, cutting bench marks, and assisting the rodman in his work.

57. The Topography Party.—The composition of the **topography party** on a preliminary survey is variable, depending on the nature of the country and the degree of accuracy required in the survey. In some cases, there is no regular topography party, the necessary topography notes being taken by the chief of party and the transitman. When a regular topography party is attached to a railroad survey party, the work of taking the topography is usually done in the manner described in *Topographic Surveying*. The topography party follows after the level party and secures the necessary data for making a contour map of the ground on each side of the line to such a distance as may be required. For ordinary work of this kind, the topography party consists of

a topographer and two assistants. The topographer uses a hand level to determine the side elevations, and keeps his notes in a regular transit book. The topography notes should be drawn to a scale of two lines per station, except in special cases, where much detail is to be shown, when a scale of four lines per station may be used.

The topographer should make full notes concerning the location of roads, property boundaries, fences, swamps, fields, forests, and streams crossed by or adjacent to the line. The character of the material along the line should be carefully noted, as well as the proximity and extent of adjacent rock outcrops. It should be borne in mind that the projection of a railroad line in hilly country is often materially affected by the character of material liable to be encountered

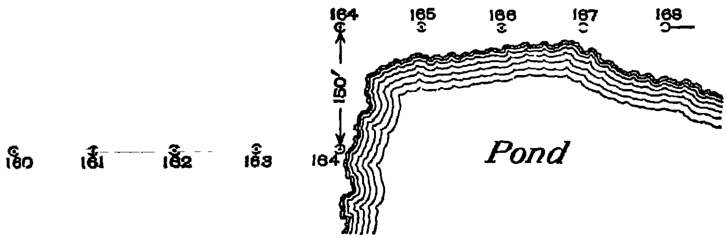

FIG 12

in cuts or that may be available for fills. The topographer's assistants should be active and quick, and capable of handling the tape or rod as may be required.

58. Offsets.—In running a preliminary survey, it is sometimes found that the line is not on the best ground that can be obtained, or that there is some obstacle ahead that must be avoided. Under such conditions, an offset to the right or left is usually made long enough to throw the line on suitable ground or to pass the obstacle. Offsets are generally made at right angles to the direction of the line, and preferably at a full station or at some division of a station that is a multiple of ten, in order to facilitate platting. The length of the offset should be carefully measured, but should not be counted in the station numbering; that is,

the station at the beginning and that at the end of the offset should be given the same number. In Fig 12 is shown a pond into which the line would run if produced beyond Sta. 164. At this station, an offset is made of sufficient length to clear the edge of the pond, and the line is continued from the end of the offset.

59. Backing Up.—Sometimes, after a survey has progressed a considerable distance, it is found that the line is on the wrong side of a valley or stream, or that a better line can be obtained by beginning at a point already passed. It is then necessary to abandon that part of the line which is in the wrong place and begin a new survey at the desired point. Such a process is called **backing up**, and is frequently necessary in difficult country. All notes of the abandoned portion of the line should be crossed out by pencil lines diagonally across the page, and the word "Abandoned" written across the face of the notes.

Notes of a survey should never be erased or destroyed, even if the survey is abandoned When such notes are crossed out, the new notes should begin at the place immediately following in the notebook, reference being made to the new page and place at the point where the old notes are allowed to stand.

60. Office Work.—At the conclusion of each day's work, the field notes, both transit and level, are carefully checked, and a plat of the line is made, either by bearings with a large paper protractor, using a parallel ruler or two triangles, or by latitudes and longitudes, carefully marking the crossings of streams and highways, and noting any important point that may enable the chief engineer to readily locate any particular section of the line. Where the country is smooth, the line may be platted to a scale of 400 feet to the inch. Rough parts of the line may require a scale of 200 feet to the inch; and where difficult country is encountered, involving detailed topographical maps, a scale of 100 feet to the inch is advisable. The line may be conveniently platted on sheets **24 in. × 30 in.** in size, numbered

in regular order, each sheet containing a part of the line on the immediately preceding sheet, so that, by matching and pinning them together, a continuous map of the line may be obtained.

The topographer will bear his proportional share of the work, consisting mainly in a detailed explanation of the notes of the day's work to the draftsman, whose principal duty is to make the contour maps. In some cases, the topographer acts as draftsman, usually, however, the transit-man plats the line and the topographer assists in platting the contours. The leveler will plat the day's levels on the continuous profile kept in the office, the rodman reading the notes. This profile should contain as full information as possible, especially when relating to highways and watercourses.

Some engineers prefer to wait for a rainy day in which to do the office work, but more make it an invariable rule to plat each night the work of the day. This practice enables the chief of party to have a complete record of his work always ready for the inspection of the chief engineer, who is likely to appear at any time. If he is his own chief, personal interest in the work would warrant him in making such a rule. Notes that are platted when fresh are always of more value than when stale. If the contour maps are to keep pace with the survey, the draftsman must be an expert. Each day he plats the work of the preceding day, so that, under the direction of the topographer, every point is covered.

61. Spur Lines.—In making a preliminary survey, it is often found that two points on the line may be connected by two or more routes, it is then necessary to run separate lines between such points in order to determine the best route. Such lines are called **branch lines**, or, more commonly, **spur lines.** The original survey line is called the **main line;** the spur lines are joined or tied to it at the required points.

Each spur line is usually designated by some letter, as line *A*, line *B*, etc. In comparing the relative merits of the different spur lines, the lines are platted together in order to compare the alinement. The different profiles may be compared either by platting them together on one

sheet of profile paper, using different-colored inks for the different lines, or by platting the profile of each line separately, using the same scale for all. In this way, the engineer, knowing the topographical features and the character of the material on the different lines, will be able to study the characteristics of each line in order to make a judicious

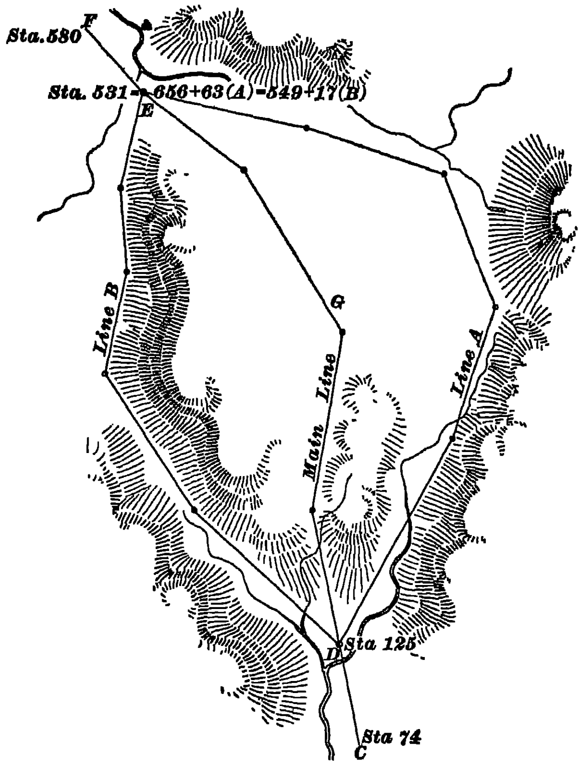

FIG 13

choice. In some cases, the merits of the different lines are so evenly balanced that it is necessary to make location surveys and estimates of cost of some or all of them, so that a final decision may be made as to which line is most suitable.

62. In Fig. 13 is illustrated a case where two spur lines have been surveyed, connecting the same two points on the

main line. The main line is represented by CGF, on which the stations are numbered continuously from C to F. The spur line A begins at Sta 125, and the numbering is carried continuously from D to the point where line A joins the main line at E. This point, which is common to both lines, is at Sta. 531 of the main line, and also at Sta 656 + 63 of line A. Such a junction point between two lines is called an **equality station;** it is entered in the notes in the form of an equation as follows:

Sta. 531 = 656 + 63 line A

In this case, the stations on line B, which begins at D and ends at E, the same as line A, are also numbered continuously from D to the junction at the common point E The station at E on line B is 549 + 17; this is recorded in the notes as follows:

Sta. 531 = 549 + 17 line B

In marking the station stakes on a spur line, the letter designating the line should be marked on each stake, just after the number of the station. For example, the stake at Sta. 625 on line A would be marked "625 A"; similarly, the stake at Sta. 510 on line B would be marked "510 B."

THE PRELIMINARY ESTIMATE

63. General Character.—After the preliminary survey is finished, an estimate should be made of the probable cost of the completed road. Sometimes, no estimate of cost is made until after the location is completed and the final grades are established Usually, however, the estimate is based on the preliminary survey, since it is frequently necessary to estimate the cost of alternative lines in order to decide which line is most advantageous to construct In either case, such an estimate is called a **preliminary estimate.**

In making a preliminary estimate, great accuracy is not necessary, and no time should be wasted in useless refinements of calculation. The estimate should be high enough to cover all probable cost, and a liberal allowance should be made to cover unforeseen contingencies that may develop

during construction. It is a common fault of engineers to underestimate the cost of a projected road Most experienced engineers make it a rule to add 10 per cent. to a preliminary estimate in order to provide for contingencies.

64. Earthwork.—In estimating for earthwork, the amount of excavation and embankment is usually calculated from the center heights as shown on the profile. The cut or fill may be assumed to begin or end at the nearest half station, as at *A*, Fig. 14. This method is somewhat inexact, but it is close enough for this purpose. The prisms are supposed to begin in the middle of one station and extend to the middle of the next station, and the center heights are taken at the full stations. In Fig. 14, the vertical broken lines represent the limits of successive prisms, and the vertical solid lines are at the full stations.

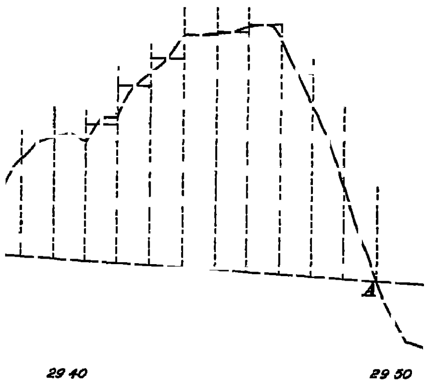

FIG 14

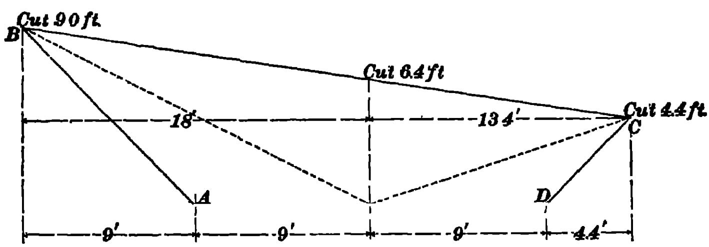

FIG 15

Earthwork quantities may be taken from a table of level cuttings, except where the transverse slope of the ground exceeds 10° from the horizontal, in which case a suitable allowance should be made for the slope The use of a table of level cuttings assumes that the cross-section surfaces are

level, and the areas are calculated from the center cuts and fills. Let Fig. 15 represent the actual cross-section at a given station, and Fig. 16 the cross-section based on the center cut. The area of the section $ABCD$ in Fig 15, calculated from the actual cross-section, is 160 78 square feet The area of the section $A'B'C'D'$ in Fig. 16, calculated from a level section, with the same center cut, viz., 6.4 feet, is 156.16 square feet, giving a discrepancy of 4.62 square feet; that is, the area of the section, calculated by level cuttings, is 4.62 square feet less than the area calculated from the actual cross-sections. This deficiency is about 3 per cent., but where the slope is very steep the difference increases rapidly. As it is the usual custom to add 10 per cent. to the estimated cost, such addition will generally cover any deficiency resulting from table calculations.

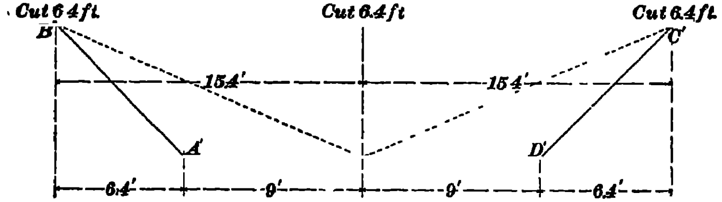

FIG 16

Where time is not an object, it is good practice to take the slopes with a clinometer and plat them on cross-section paper. The estimate thus obtained will be a close approximation to the actual quantities handled in the work of construction.

For work in the northern and middle American states, the following rates of slope are standard. for embankments, $1\frac{1}{2}$ horizontal to 1 vertical; for earth cuts, 1 horizontal to 1 vertical; and for rock cuts, $\frac{1}{4}$ horizontal to 1 vertical In the western and southern states, it is the usual custom to give to cuts the same slope as to embankments, viz., $1\frac{1}{2}$ horizontal to 1 vertical.

65. Trautwine's "Engineers' Pocketbook" contains complete tables of level cuttings for standard widths of roadway, both single and double track. The slopes are given for earthwork, both excavation and embankment. The

level, and the areas are calculated from the center cuts and fills. Let Fig 15 represent the actual cross-section at a given station, and Fig. 16 the cross-section based on the center cut. The area of the section *ABCD* in Fig. 15, calculated from the actual cross-section, is 160.78 square feet. The area of the section *A′ B′ C′ D′* in Fig. 16, calculated from a level section, with the same center cut, viz., 6.4 feet, is 156.16 square feet, giving a discrepancy of 4.62 square feet; that is, the area of the section, calculated by level cuttings, is 4.62 square feet less than the area calculated from the actual cross-sections. This deficiency is about 3 per cent., but where the slope is very steep the difference increases rapidly. As it is the usual custom to add 10 per cent. to the estimated cost, such addition will generally cover any deficiency resulting from table calculations.

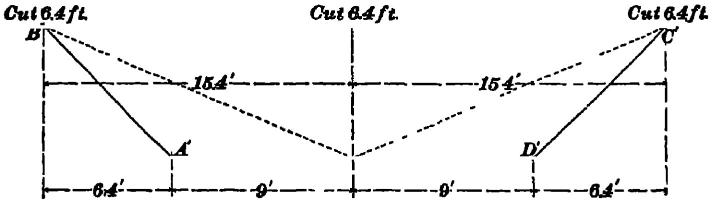

FIG 16

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quantities are calculated for sections 100 feet apart. If the sections are taken at intervals of less than 100 feet, the quantities will be proportionally less. Table I is a part of the table given in Trautwine's book for single-track excavation, roadway 18 feet wide, slopes 1 horizontal to 1 vertical

The use of this table is as follows: Suppose that the center cut at Sta. 10 is 1.5 feet and the center cut at Sta. 11 is 3 feet. The sum of these two center cuts is $1.5 + 3.0 = 4.5$ feet. The mean or average center cut for these stations is, therefore, $4.5 \div 2 = 2.2$ feet, nearly.

Referring to the table, we find, in the column headed Depth of Cut, the figure 2, and on the same horizontal line, under the column headed 2, we find 164.6, which

TABLE I

TABLE OF LEVEL CUTTINGS

Depth of Cut Feet	0	1	2	3	4	5	6	7	8	9
	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards
0	0	6 7	13 5	20 3	27 3	34.3	41 3	48 5	55.7	63 0
1	70 4	77 8	85 3	92 9	100 6	108 3	116 1	124 0	132 0	140 0
2	148 1	156 3	164 6	172 9	181.3	189 8	198 4	207 0	215 7	224 5

is the number of cubic yards of material to be excavated between Sta. 10 and Sta. 11.

The quantities are given for center cuts from .1 foot to 60 feet. For cuts greater than 60 feet, the quantities are calculated for each ½ foot to 80 feet, and after that for whole feet.

66. The character of the material to be excavated is largely a matter of conjecture The notes taken by the locating engineer and the topographer concerning the surface formation, rock outcrops, etc. will usually be of considerable assistance in making the classification. In many cases, however, the appearance of the surface of the ground does not afford a true indication of the material below. Where it is

required to determine, with considerable accuracy, the nature of the material that is likely to be encountered in cuts, soundings or borings are made to the required depth below the surface. Soundings in earth are made with an iron or steel sounding rod of suitable length and having its lower end sharpened to a point. A good form of sounding rod consists of a round steel rod from $\frac{3}{8}$ to $\frac{1}{2}$ inch in diameter and from 6 to 10 feet in length. Borings can be made with an ordinary auger from $1\frac{1}{2}$ to 2 inches in diameter, having a stem or shank of suitable length with a wooden handle attached to its upper end.

67. Culverts.—In estimating the quantity of masonry for culverts, it is a good plan to use a diagram or table giving the volume of masonry in any standard type of culvert for embankments having a given width of roadbed, for given center heights. It is usually safe to base the estimate for a given culvert on the greatest center height, as the culvert will be built at or near the deepest part of the embankment. This rule is applicable to a pipe culvert in estimating the amount of pipe required for a given center height of fill.

68. Bridges, Trestles, Piers, and Abutments.—The volume of masonry required for bridge piers and abutments can be tabulated or expressed by a diagram for different heights. Then, for any given height, the quantity of masonry can be taken direct from the table or diagram. In estimating for timber trestles or bridges, the amount of timber required for the caps and the floor system is constant per unit of length, and may be taken at a given amount per running foot, regardless of the height of the structure. The length of the posts and the bracing will vary according to the height of the trestle, and the timber required for them is estimated according to the center height. Piling is estimated according to the number of linear feet of piles required. Timber used in bridges or trestles is estimated by the thousand feet, board measure. Wooden bridges of moderate span are sometimes estimated at a fixed price per

thousand feet, board measure, for the timber required, and a fixed price per pound for iron for bolts, spikes, and washers; usually, however, a special estimate is made for each bridge. In making estimates for iron or steel viaducts or bridges, it is customary to make a special estimate for each structure.

69. Form of Estimate.—The quantities of earthwork and other materials having been computed, they should be tabulated for the complete estimate. A complete preliminary estimate gives, in detail, the approximate quantities of all material to be used or handled in the work of construction, as well as the probable cost of such work. The different items entering into the estimate are usually classified according to their character, and prices are given according to the various units of measurement employed.

Under the heading of earthwork is included all excavation and embankment Excavation is usually classified as earth, loose rock, or solid rock. Where different kinds of material are found, other classifications are sometimes used; as, for example, hard pan, gravel, etc. A good form for a preliminary estimate for a projected railroad is shown below.

ESTIMATE OF COST—*A* & *B* RAILROAD

Clearing 625 acres at $20 per acre	. . . . .	$ 12500
Earth excavation	900,000 cu yd at 17c .	153000
Loose-rock excavation	300,000 " " " 40c	120000
Solid-rock excavation	200,000 " " " 80c .	160000
Overhaul, exceeding 600 ft	300,000 cu yd at 1c.	3000
Borrowed embankment	80,000 cu yd. at 17c .	13600
Piling	12,000 lin ft at 25c.	3000
Framed trestles	300,000 ft B M at $35 per M .	10500
First-class masonry	2,800 cu. yd at $12 . .	33600
Second-class masonry	4,200 " " " 8 . .	33600
Box culvert masonry.	2,300 " " " 5 . .	11500
Dry-rubble masonry	2,600 " " " 4 . .	10400
Concrete masonry	3,000 " " " 6 .	18000
Riprap	2,000 sq " " 1 50 . .	3000
Cast-iron pipe culverts.	40,000 lb at 3c.	1200
Vitrified " "	1,800 lin ft at 1 50 . .	2700
Total, exclusive of bridges and track	. . . .	$589600
Add 10 per cent	. . . .	58960
Total cost for grading and trestles	. . . . .	$648560

LOCATION

70. Definition.—In general, **location** is the operation of fitting the line to the ground in such a manner as to secure the best adjustment of the alinement and grades, consistent with an economical cost of construction. The term *location* is also applied to the position of the line on the ground, "the line" being always understood to be the center linc of the road.

71. Methods of Location.—There are two general methods employed for making a road location. The first method is used in ordinary country, where no topography party has been employed on the preliminary survey, the topographical features being shown by means of sketches drawn by the chief of party and the transitman in their notebooks The preliminary line is then used, either as a base from which to project a location on the ground or as a guide from which to study the ground with a view of selecting a suitable location. In either case, the tangents are laid, run to their intersections, and then connected by proper curves, all the work being done directly on the ground.

The second method of location is usually employed in a rough country, where complete topographical notes have been taken on the preliminary survey. A complete topographical map is first drawn, and the location is then projected on the map. This **paper location,** as it is called, requires considerable skill and much study; it is sometimes made by the chief engineer himself. If a careful preliminary survey has been made, the location will vary but little from the preliminary line, and the latter line is treated as an approximate location from which the final location can be platted. Which method to use depends to a great extent on local conditions of topography. The second method, however, is generally preferred.

PAPER LOCATION

72. Advantages of Paper Location.—As already stated, the location may be made on the ground, without the intervention of maps, but this method is seldom used except in a smooth level country where a straight line is the best location. In a region where the ground is broken and hilly, this method of direct location tends to follow too closely the variations in the surface, and generally requires excessive curvature The use of a contour map affords a much larger view of the country than is possible on the ground, so that a better adjustment of the line can be made and consequently a much better alinement secured.

73. General Description of the Method.—When the location is projected on the map, the line is laid down on the contour maps, which contain all the information accumulated by the preceding surveys. The grade for each station is taken from the preliminary profile, and marked on the contour maps opposite the corresponding station. This is readily done, as the contours are but 5 feet apart, and intermediate elevations can easily be estimated. These grade points are commonly marked by small red dots enclosed in small circles of the same color; they show where the plane of the grade would cut the surface of the ground. A piece of fine thread is then stretched, covering as many of these points as possible, and a pencil line drawn along the thread. This pencil line will locate a tangent on the map. In the same way, any number of tangents may be located.

74. The Curved Protractor.— A **curved protractor** affords a quick and convenient method of fitting curves to the tangents. An instrument of this kind is shown in Fig. 17; it consists of a series of curves of different radii, drawn on a sheet of some transparent material, such as horn or mica, and to the same scale as the contour map. A curve protractor suitable for field or office use can be made in the following manner:

On a piece of tracing cloth of suitable size, draw two lines at right angles to each other, and use their intersection as a

center from which to draw concentric semicircles, to the same scale as was used for the map—say 200 feet per inch. Begin with an 8° curve, and draw the successive curves at intervals of 30 minutes up to 15°, or higher, if required. Next reverse the sheet and draw the curves of larger radii, at intervals of 30 minutes between 8° and 1°. These curves need not be concentric, but their centers should be on the same vertical line. The resulting figure will be similar to that shown in Fig. 17.

Such a curve protractor can be readily drawn with an ordinary set of drawing instruments; it can be rolled up in a map or profile and carried into the field without injury. When in use, it is laid on the contour map at or near the

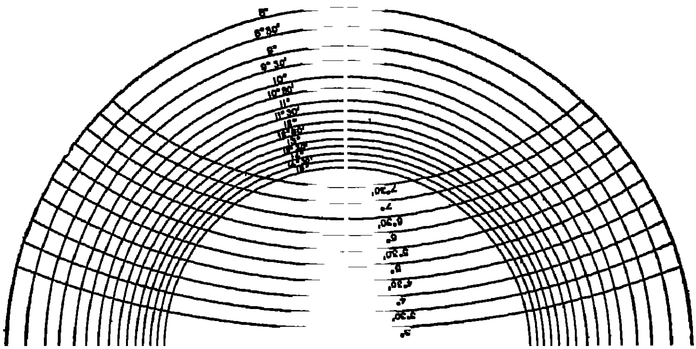


Fig 17

junction of the two tangents that are to be connected with a curve. The curve protractor is then shifted until a suitable curve is found that will fit the topography and will close the angle between the tangents as required, the P. C. and the P. T. are then marked on the tangents at the extremities of the connecting curve. Having determined the degree of curve to be used for connecting the tangents, the angle of intersection can be measured by a protractor, or calculated if preferred, and the tangent distances are then scaled off Great accuracy in measuring the intersection angles on the map is not essential, since the projected tangents when run out on the ground will not always correspond exactly with their positions on the map.

75. The Adjustment of Gradients.—The adjustment of the grade line requires considerable skill and much sound judgment. Such work should be done by the locating engineer, since he is familiar with the local conditions and the general character of the topography along the line. Grade lines are usually projected in such a manner as to equalize as far as possible the quantities of excavation and embankment; this, however, is not a fixed rule Local conditions—such as crossing under the tracks of another railroad, or beneath a street or highway, or over a ridge or summit on the maximum gradient—usually require excess of excavation over embankment. In a flat swampy region, the embankment should be built high enough to form a solid,

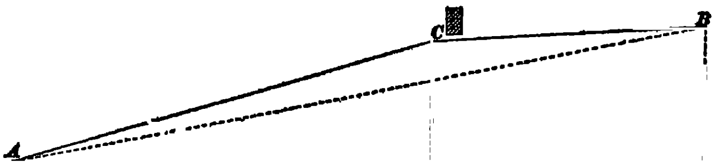


FIG 18

well-drained roadbed; in such a case, the embankment will exceed the excavation.

Stopping places for trains, such as stations, water tanks, etc., should never be located at the foot of a heavy gradient; they should preferably be located where the grade is level or nearly level. If a stopping place is necessary on a long, heavy gradient, it is usually preferable to break the grade, as at C, Fig. 18, and introduce a short piece of light grade, as CB, than to have a uniform heavy grade, as AB. The gradient AC is steeper than the original gradient AB, but this arrangement is preferable, provided that the portion from A to C is within the limit of the maximum gradient used on the road.

76. Example of Paper Location.—The platting of a paper location is illustrated in Fig. 19. Here the line follows the valley of Bear River, and the gradient is determined by the slope of the stream. The gradient adopted is

.5 per cent., or .5 foot per station. The preliminary line is shown dotted, and the located line is drawn full.

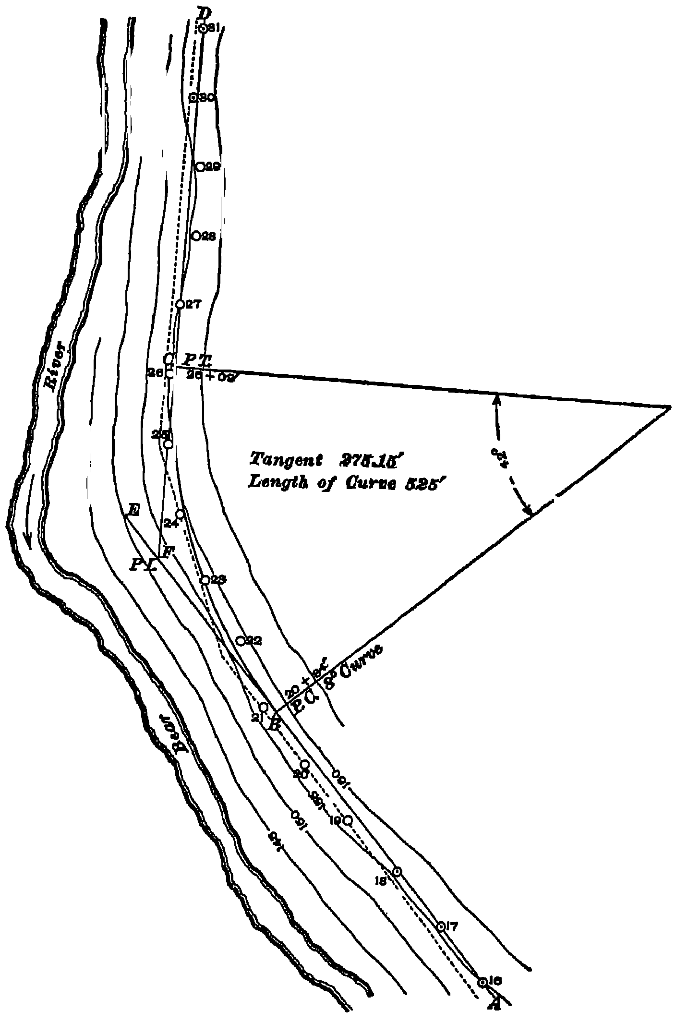


Fig 19

Let the grade elevation for Sta. 16 be 155 feet; the grade elevation for Sta. 17 will, therefore, be 155 feet + .5 foot = 155.5 feet. The grade elevation for Sta. 18 will be

155.5 + .5 = 156 feet. By the same process, the grade elevation is found for each station shown in the plat; and the required grade elevation for each station is designated on the contour map, opposite the corresponding station of the preliminary line, by a small dot enclosed in a circle. A line joining the points thus designated will be the grade contour, or the line where the required gradient meets the surface of the ground. It is not practicable, however, to follow the grade contour exactly with the located line; but the location should be as close to the grade contour as the conditions of curvature and the nature of the ground will permit. The tangents AB and CD are projected so as to conform as closely as practicable to the grade contour; they are produced until they intersect at a point F, which is called the P. I. The exterior angle EFD, or the angle of intersection, which is usually written I, is then measured with a protractor. In order to determine what curve will connect the two tangents and fit the ground to the best advantage, a curve protractor is used in the manner previously described. If a curve protractor is not available, a pair of compasses may be used; they are set to different radial lengths and tried until the best curve is found. When spiral or transition curves are used, an offset is left at each end of the circular curve, between the curve and the tangent. Each offset should be long enough to admit of the use of a spiral curve of the required length.

77. Field Notes From the Paper Location.—After the located line has been projected on the contour map, the engineer should make careful notes of the required distances between the preliminary line and the projected location at suitable points In taking notes from the paper location for use in the field, the points fixing the positions of the several tangents are carefully scaled from fixed points on the preliminary line, so that, in case it is necessary to swing a terminal tangent, the desired position for the tangent can be readily determined by measurement from some fixed point The field notes for the location shown in Fig. 19 can be written as follows:

Set hubs 20 feet right of Sta. 16 and 10 feet right of Sta. 22; pass tangent through the two points thus found, and produce tangent to a point opposite Sta. 24. Set hubs 9 feet right of Sta. 25 and 10 feet right of Sta. 31, pass tangent through the two hubs, and produce to an intersection with first tangent. Measure the angle of intersection, calculate tangent distances from P. I. and set hubs for P. C. and P. T. of an 8° curve to connect the two tangents.

This form of notes is suitable for field use when the country is open and the tangents are to be run to their intersection. In case it is not required to produce the tangents to their intersection, the following form of notes may be used:

Set hubs 20 feet right of Sta. 16 and 10 feet right of Sta. 31. Pass tangent through these points, and make Sta 20 + 84 = P. C. of 8° curve to the right for 42°. At P. T. of this curve, Sta. 26 + 9, turn tangent, which should pass 10 feet right of Sta. 31 of the preliminary line. If the terminal tangent misses the required position, lengthen or shorten the curve, as the case may be, so as to throw the tangent in the required position.

The engineer, in making a location, should bear in mind that the main object of the survey is to get the located line on the best ground, and that this point is more important than a close agreement with the measurements of the preliminary line. It is not to be expected that the measurements of the two lines will agree very closely; the preliminary line should be used only as a guide to the general position of the location.

78. Curvature.—There is no fixed rule for limiting curvature, but for a permanent track it is desirable to have the curvature as easy as possible. If construction funds are limited, and it is required to economize on the cost of the road, sharp curvature may be used, which can be eliminated or improved at a later time, when the business of the road increases sufficiently to justify the work. For all ordinary traffic conditions, it is good practice to use such

curves as will best conform to existing topographical conditions. Any curve up to 10° will be no obstacle to a speed of 35 miles per hour, the average speed of passenger trains. This affords a range in curvature that will meet the requirements of most localities

In Fig. 20 is illustrated a case where sharp curvature is used advantageously to reduce the cost of construction. The line follows the course of a stream in a narrow valley, whose sides are steep and rough Unless the prospective business is large and the railroad company is financially strong,

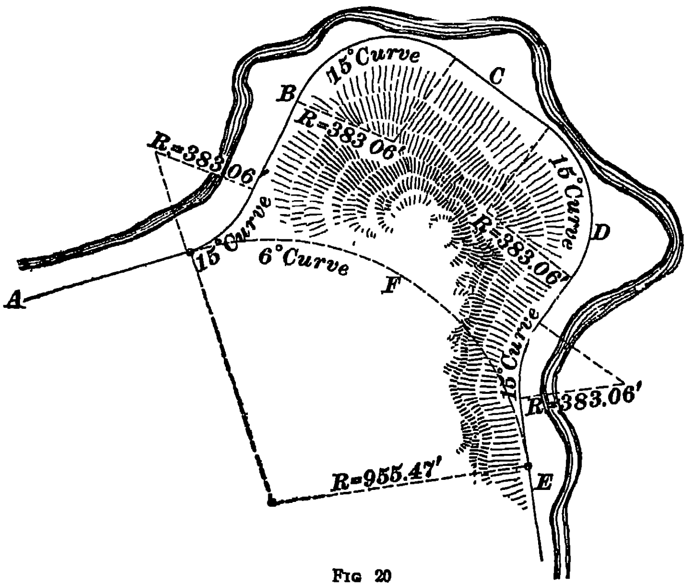


FIG 20

it will be a much better policy to build the line *ABCDE*, using curves as high as 15°, and reducing cost to a minimum, than to build the line *AFE*, giving a single curve of 6°, but requiring a heavy rock cut at *F*, or perhaps a tunnel at that point. The line *AFE* is always possible, and when the road has built up a paying traffic and finances are easy, the cut or tunnel at *F* can be made without interfering in any way with traffic, and in all probability the work can be done

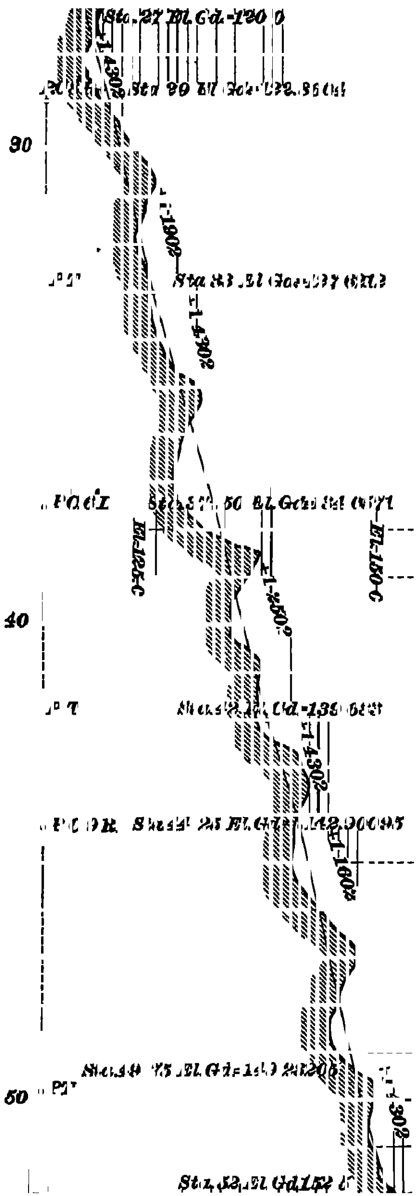


FIG 21

more cheaply than was possible at the time the temporary line *ABCDE* was built.

79. Compensation for Curvature.—The effect of curvature on a railroad line is to cause a resistance to the movement of trains; such resistance is assumed to vary inversely as the length of radius or directly as the degree of curvature, although it is readily demonstrated that this law is far from accurate. When a curve occurs on a gradient, the effect of the curve resistance on ascending trains is practically the same as increasing the gradient. It is customary in fixing the final grades to lighten the grade on a curve an amount sufficient to offset the resistance due to the curvature. This operation is called **compensating for curvature.** The usual rate of compensation for curvature is .03 to .05 foot per hundred feet per degree

of curvature. For example, where the maximum gradient on tangents is 1 per cent., the maximum gradient on a 6° curve, allowing a compensation of .03 foot per degree, would be $1 - (.03 \times 6) = .82$ per cent. If a compensation of .05 foot per degree were made, the grade on a 6° curve would be $1 - (.05 \times 6) = .70$ per cent.

80. Final Grade Lines.—The establishing of **final grade lines** is illustrated in Fig. 21, where the uncompensated grade is 1.3 per cent., and the compensation for curvature, as shown in the final grade line, is .03 foot per degree. The location notes for this line are as follows:

Stations	Intersection Angles
52 + 00	End of grade
49 + 75 P. T.	
44 + 25 P. C. 9° R.	49° 30′
42 + 00 P. T.	
37 + 50 P. C. 6° L.	27° 00′
33 + 00 P. T.	
29 + 00 P. C. 8° R.	32° 00′
27 + 00	Beginning of grade

The profile is made to standard scales; namely, horizontal, 400 feet = 1 inch, vertical, 20 feet = 1 inch. The elevation of the grade at Sta. 27 is fixed at 120 feet, and at Sta. 52, at 152.5 feet, giving between these stations an actual rise of 32.5 feet and an uncompensated grade of 1.3 per cent. These grade points are marked on the profile with small circles. The total curvature between Sta. 27 and Sta. 52 is $108\frac{1}{2}°$. The resistance due to each degree of curvature being taken as equivalent to an increase of .03 foot in grade, the total resistance due to 108.5° is equivalent to $.03 \times 108.5 = 3.255$ feet additional rise between Sta. 27 and Sta. 52. Hence, the total theoretical grade between these stations is the sum of 32.5 feet, the actual rise, and 3.255 feet due to

curvature, or 35.755 feet. Dividing 35.755 by 25, the number of stations in the given distance, we have $35.755 \div 25 = +1.4302$ feet, as the grade for tangents on this line. The starting point of this grade is at Sta. 27. The P. C. of the first curve is at Sta. 29, giving a tangent of 200 feet = 2 stations, As the grade for tangents is +1.4302 feet per station, the rise in grade between Stas. 27 and 29 is $1.4302 \times 2 = 2.8604$ feet. The elevation of grade at Sta. 27 is 120 feet, and the elevation of grade at Sta. 29 is $120 + 2\ 8604 = 122\ 8604$ feet, which is recorded on the profile as shown in the diagram, with the rate of grade, viz., +1.4302, written above the grade line. The first curve is 8°, and, as the compensation per degree is .03 foot, then, for 8°, or a full station, the compensation is .03 foot $\times 8 = .24$ foot The grade on the curve will, therefore. be the tangent grade minus the compensation, or $1.4302 - .24$ foot $= +1.1902$ feet per station. The P. C. of this curve is at Sta. 29, the P. T. at Sta. 33, making the total length of the curve 400 feet = 4 stations. The grade on this curve is +1.1902 feet per station, and the total rise on the curve is $1.1902 \times 4 = 4.7608$ feet. The elevation of the grade at the P. C. at Sta. 29 is 122 8604; hence, the elevation of grade at the P. T. at Sta. 33 is $122\ 8604 + 4.7608 = 127.6212$ feet, which is recorded on the profile together with the grade, viz., +1.1902, written above the grade line. The P. C. of the next curve is at Sta. 37 + 50, giving an intermediate tangent of 450 feet = 4 5 stations. The grade for tangents is +1.4302 feet per station; hence, the total rise on the tangent is $1\ 4302 \times 4.5 = 6.4359$ feet. Adding 6.4359 feet to 127.6212 feet, the elevation of grade at Sta. 37 + 50 is found to be 134 0571 feet, which is recorded on the profile, together with the rate of grade for tangents.

The next curve is 6°, and the compensation in grade per station is .03 foot $\times 6 = .18$ foot. The grade on this curve will, therefore, be $1.4302 - 18 = 1.2502$ feet per station. The length of the curve is 450 feet = 4 5 stations, and the total rise in grade on this curve is +1.2502 feet $\times 4.5 = 5.6259$ feet. The elevation of the grade at Sta. 37 + 50, the P. C. of the curve, is 134.0571. The elevation of the grade

at Sta. 42, the P. T , is therefore 134.0571 + 5.6259 = 139.683 feet, which is recorded on the profile together with the rate of grade on the 6° curve, viz., +1.2502. The P. C. of the next curve is at Sta. 44 + 25, giving an intermediate tangent of 225 feet = 2 25 stations. The total rise on the tangent is, therefore, 1.4302 × 2.25 = 3.21795 feet. The elevation of grade at the P. T. at Sta. 42 is 139 683; therefore, the elevation of grade at Sta. 44 + 25 is 139 683 + 3 21795 feet = 142 90095 feet, which is recorded on the profile together with the grade, +1.4302.

The last curve is 9°, and the compensation in grade per station is .03 foot × 9 = .27 foot. The grade on this curve is, therefore, 1 4302 − .27 = 1.1602 feet per station. The length of the curve is 550 feet = 5.5 stations, and the total rise on the curve is 1.1602 × 5 5 = 6 3811 feet The elevation of grade at Sta 44 + 25, the P. C. of the 9° curve, is 142.90095; hence, the elevation of grade at the P. T., at Sta. 49 + 75, is 142.90095 + 6 3811 = 149.28205 feet, which is recorded on the profile together with the grade, +1 1602. The end of the line is at Sta. 53, giving a tangent of 225 feet = 2.25 stations. The rise on this tangent is 1 4302 × 2 25 = 3.21795 feet, which is added to 149.28205, the elevation of the P. T at Sta. 49 + 75. The sum, 152.5 feet, is the elevation of grade at Sta. 52.

The sum of the partial grades should equal the total rise between the extremities of the grade line. The points where the changes of grade occur are marked on the profile in small circles, which are connected by fine lines representing the grade line. These points of change are projected on a horizontal line at the bottom of the profile. The portions of this line that represent curves are dotted, and the portions that represent tangents are drawn full The points of curve P. C. and P. T. are marked in small circles on this horizontal line, and are lettered as shown in the diagram.

Where the grades are light and the curves have large radii, there will be no need of compensation for curvature. Where the grades exceed .5 per cent. and the curves 5°, compensation should be made.

LOCATION FIELD WORK

81. Work of the Locating Party.—The operation of laying out the line of the road on the ground is called a **location survey.** The organization of the survey party is practically the same for location as for the preliminary survey, except that usually no topography party is required on location, and a back flagman is added to the transit party.

The locating engineer projects the location either by making complete alinement notes from the contour map, to be followed in the field, or by selecting suitable points on the ground through which to run the location. In either case, he should accompany the party in the field, and exercise a general supervision over the work, keeping constantly on the lookout for possible improvements in the line. He should take careful notes of all stream crossings, and make rough estimates of the drainage areas of the streams crossed, to serve as a guide in estimating the areas of the various openings required, and also to assist in determining the character of bridges to be used He should note the nature of the ground over which the line passes, and determine, as far as possible, the composition of cuts, by means of a sounding rod or an auger, if there is doubt as to the existence of rock.

82. The transitman on location should keep full notes of the alinement and also of such topography as is required. He should check all computations for deflections on curves, noting both the magnetic and the calculated bearings of all tangents. The bearing of each tangent is determined, from that of the tangent next preceding, by the total deflection angle contained in the connecting curve. The bearing of a course at the beginning of a survey is first determined by the needle or by comparing it with the bearing of a line whose direction is known; the bearing of each successive course or tangent is then determined by calculation. The needle is not used on location, except as a check on the bearings of the tangents, and as a means of determining the bearings of roads, fences, land lines, etc.

83. On location, a back flagman is required to give back sights to the transitman. His duty consists in holding the transit rod in a vertical position on the required point for each sight.

84. Stakes are placed at all 100-foot stations, at intervals of 50 feet on curves, and at substations. Turning points, such as the P. C. or P. T. of a curve, or intermediate transit points, are marked by hubs or plugs driven flush with the surface of the ground, the exact point being marked by a nail or tack driven in the top of the plug. At each transit point, a witness stake should be driven about 18 inches to the left of the line and facing the hub. If the transit point is at a full station, the number of the station is marked on the witness stake; if at a substation, the number of the next preceding station and the plus should be marked on the witness stake. If, for example, a hub is set on line 60 feet from Sta. 101 and between Stas. 101 and 102, the witness stake for the hub is marked 101 + 60.

85. The level party will have more time for their work on location than on the preliminary survey, since the progress of the transit party is necessarily slow on location. The elevations at stations and substations should be carefully determined, and plus distances for intermediate readings should be measured with a tape. In some cases, small round pegs, about ¾ inch in diameter and from 4 to 6 inches long, are driven at each station; they are driven flush with the ground, and the rod reading for the station elevation is taken on the top of the peg. Bench marks on location should be placed on the edge of the right of way, in order that they may be safe from disturbance by clearing or other work during construction Bench marks should be established at intervals of from 1,200 to 1,500 feet; they should preferably be made at or near the ends of long cuts or embankments, and at points on the line where important structures, such as culverts, trestles, abutments, etc , are to be built

86. Topography notes on location, if taken at all, are usually taken by the transitman or the chief of party. If the

preliminary survey has been well made, there will usually be little need for the taking of much topography during the location survey.

87. The locating engineer, the transitman, and the leveler should all make full notes on location concerning the details of topography and of local conditions along the line. Where a stream of considerable size is crossed, careful cross-sections should be made by means of soundings, as described in *Hydrographic Surveying*. Borings or soundings should also be made at suitable places on the banks or in the bed of the stream, in order to ascertain the depth to rock or hard pan, and to determine the nature of the foundations for bridge piers and abutments. Inquiries should be made concerning the amount of rainfall, the height and duration of floods, etc., and all possible information concerning the watercourses should be obtained that may be of value in proportioning the sizes of bridge openings and waterways. Land and property lines are located by noting the station or plus where they cross the survey, and also by measuring the angle made by the land line with the line of the survey.

88. Tangents.—If the country is open, the tangents are run to their intersection, and the angle of intersection is measured with the transit. The tangent distances are then measured both ways from the P. I. (point of intersection), and hubs are set for the P. C. and the P. T. of the required curve.

If the country is heavily timbered or is rough and rugged, the tangents are not usually run to their intersection. In such cases, the notes of the paper location are followed out by measurements from the preliminary line. Each tangent is run to the P. C. as projected, the projected curve is run in, and the next tangent is started at the P. T. of the curve. In case the curve does not terminate exactly as calculated, the terminal tangent can be swung into the required position by lengthening or shortening the curve.

89. Sections.—The line is divided into lengths of about 1 mile each, called **sections**, which are numbered in regular

order, the first mile of the line being section 1, the second mile section 2, and so on. At the divison points, that is, where one section ends and another begins, posts are set up with boards attached, facing in both directions, with the numbers of the sections toward which they face written in large figures. (See Fig. 22.)

Fig 22

The section boards enable one to readily locate any particular part of the line.

90. Field Profiles.—The profile should be kept platted as fast as the line is located, in order that the chief of party may know how nearly the actual profile approximates the theoretical one (the one that is made from the paper location) and what changes may be necessary.

FINAL LOCATION

91. After the right of way has been cleared, affording an unobstructed view of the ground, it will frequently be seen that slight changes in the located line will greatly reduce the cost of construction, and not until such changes are made will the engineer have made the **final location.**

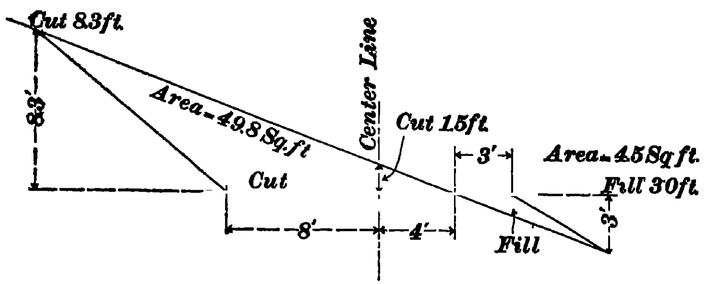


Fig 23

None but experienced engineers can understand how a slight change in location, especially on a side-hill line, can so greatly affect cost; and it is first cost that generally determines the success or failure of the enterprise.

Figs. 23 and 24 may serve as illustrations of a bad and a good location, respectively. Fig. 23 shows a defective location, which can readily be avoided by a little conscientious work and common sense. This location may be replaced by that shown in Fig. 24, which is far superior.

Side hills afford an opportunity for almost the cheapest form of construction. A **grade line**—that is, a center line coinciding with the surface of the ground, as in Fig. 24—can, unless rock is encountered, be graded with pick and shovel alone, the men casting the material taken from the cut directly into and making the fill. The area of the cut in Fig 23 is 49.8 square feet, while the area of the fill is but 4 5 square feet, leaving an excess of excavation of 45.3 square

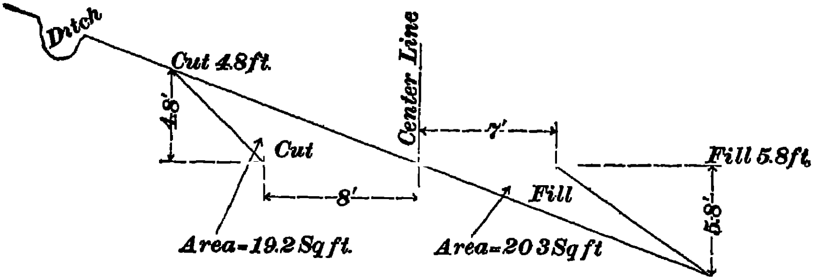


FIG 24

feet, or ten times the area of the fill. There is no way by which this excess of material can be utilized, it must, therefore, be wasted, as has been the labor of excavating it. By moving the center line 4 feet to the right, the cross-section shown in Fig. 24 is obtained, in which the calculated areas of cut and fill are as follows: cut, 19 2 square feet, fill, 20.3 square feet—a difference of less than 1 square foot, with the excess on the right side, for a ditch should be made 4 feet from the top of the upper slope to prevent the washing down of the slope, and this material will more than equal the excess of the fill over the cut.

92. The Location Profile.—The profile of the located line should have the ground line drawn in India ink, shaded on the lower side with gray. The grade line should be drawn

in red ink or carmine; each change in the rate of grade should be marked by a small circle enclosing the grade point. The elevation of the grade line at each grade change and the rate of grade between successive changes should be expressed in figures The bridging and the various openings should be plainly shown; the character of each bridge and opening should be designated; and the names of the different streams should be written on the profile. The nature of the country, whether open or timbered, should be stated In some cases, estimates of earth work for the various cuts and fills are written on the profile, also the quantities of construction material required at the different bridge and culvert openings. The alinement is shown near the bottom of the profile, that portion of the line corresponding to tangents being drawn in full lines, and the curves represented by broken lines. The stations of the points of curve and tangency, as well as the terminal points of spirals, are properly marked and numbered.

93. Map of Final Location.—After the final location is made, a complete map of the line should be drawn. Such a map should show the alinement in detail, including the P C. and P T of each curve, the degree of curvature, the terminal points of spirals, and all P. C C 's. The central angle of each curve should be given, and the correct bearing of each tangent should be written near the line. The map should also show the limits of the right of way, the positions and bearings of property lines, and the positions of known land corners, when they lie within the limits of the map. The names of property owners whose property is on or adjacent to the right of way, and complete details of local topography, including buildings and other structures, should be shown. The nature of the country and the character of the clearing should also be indicated. The center line is preferably drawn in red ink, and the right-of-way boundaries, the topography, and other details, in India ink. The map may be drawn on good Manila paper or on heavy mounted paper, as preferred. The map of the final location is usually

drawn continuously on a roll of paper of suitable size; but there is no fixed rule on this point, and sheets of convenient size may be used if preferred.

RIGHT OF WAY

94. The **right of way** is the strip of land that must be acquired for the construction of the road. Before construction can be commenced, the right of way must be secured. This matter is always attended with more or less difficulty. The standard width of right of way is 100 feet, though in some cases but 4 rods, or 66 feet, is adopted, with additional widths wherever needed

Where the local needs for the road are great and the enterprise popular, much right of way is often donated, a nominal sum, usually one dollar, being paid as consideration. The ordinary mode of securing right of way, however, is by direct purchase. The company employs an agent specially fitted for this business, who makes the most advantageous bargains possible with the different owners When there is failure to agree on price, a common alternative is to leave the question to three arbitrators; each of the parties to the transaction choosing one, and both parties agreeing on the third. Occasionally, an owner, taking advantage of the situation, attempts extortion, in which case the only recourse is to the law of eminent domain. Articles of condemnation are taken out and appraisers appointed by the court, who fix the amount of compensation. This process is always attended by expense, delay, and vexation, and should be only a last resort.

95. Right-of-Way Maps.—A careful survey is made of each separate piece of property bought for right of way or station grounds, and stone corners are established for future reference These surveys should be platted in a "right-of-way" book in the same order in which they occur on the line, and a copy of the contract for the property, together with a description of it, should be written either

on the same page or on that adjoining the plat. The plat should specify content, boundaries, corners, and any information that may be of future use. A copy of the contract and a tracing of the plat are delivered to the person or persons from whom the property is bought.

VERTICAL CURVES

96. Definitions.—If the grade of the center line of track changes at any point, the two grade lines that intersect at this point form with each other an angle more or less

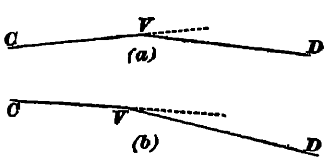


FIG 25

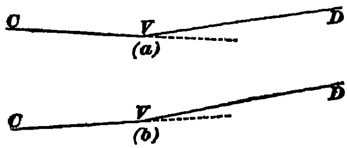


FIG 26

abrupt. If this angle points upwards, it is called a **spur**; if it points downwards, it is called a **sag**.

The angles CVD in Figs 25 and 27 are spurs; the angles CVD in Figs. 26 and 28 are sags If either grade line is produced beyond the vertex of the angle, a spur will

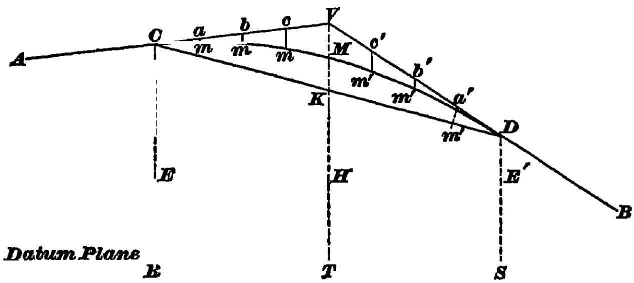


FIG 27

evidently occur whenever the other grade line lies below the grade line that is produced (see Fig. 25); otherwise, a sag will occur (see Fig. 26). In either case, the angle must be rounded off by the introduction of a curve called a **vertical curve.**

In the following articles, a brief discussion of vertical curves will be given. Circular curves and spirals are treated in *Circular Curves* and *The Transition Spiral*, respectively.

97. Vertical Curve at a Spur.—If AV and BV, Fig. 27, are two grade lines meeting at V, a vertical curve CMD must be introduced joining these lines. Between C and D, the actual grade is established along the vertical curve CMD, instead of along CV and VD. The projections RT and TS of the distances VC and VD from the vertex to the points at which the vertical curve begins and ends are always chosen equal. If K is the middle point of the straight line CD, the vertical curve is always so chosen that it will bisect VK—that is, so that $VM = MK$.

98. Let E be the elevation of C, Fig 27, E' that of D, and H that of V, so that $E = RC$, $E' = SD$, and $H = VT$. Then, for the elevation of K,

$$KT = \tfrac{1}{2}(CR + DS) = \tfrac{1}{2}(E + E')$$

and for that of M,

$$MT = \tfrac{1}{2}(TV + TK) = \tfrac{1}{2}\left(H + \frac{E + E'}{2}\right)$$

Subtracting the elevation of M from that of V, the remainder will be the distance VM from the vertex to the vertical curve.

$$VM = H - \tfrac{1}{2}\left(H + \frac{E + E'}{2}\right) = \tfrac{1}{2}\left(H - \frac{E + E'}{2}\right) \qquad (1)$$

The distance VM is called the **correction in grade** at the point V.

Vertical curves are always made parabolic. It is a property of the parabola that the correction in grade am at any point a is given by the equation,

$$am = VM \times \left(\frac{Ca}{CV}\right)^2 \qquad (2)$$

The distance $CV = VD$ is always made a whole number of stations; and, to simplify the work, the grade stakes a, b, c, etc. are so set that they divide the distance CV into a number of equal parts. The corrections in grade at points

a', b', and c' along $D\,V$ are equal to those for the corresponding stakes along $C\,V$. That is, if $Ca = D\,a'$, then $a\,m = a'\,m'$; if $C\,b = D\,b'$, then $b\,m = b'\,m'$, etc.

EXAMPLE —A + 4-per-cent grade meets a − 5-per-cent. grade at Sta 190, the elevation of which is 161 3 feet If a vertical curve 400 feet long is inserted, what is the correction in grade and the corrected grade elevation at each station and half station?

SOLUTION —In this example, $VC = VD = 200$ ft
Elevation of C is $161\ 3 - 2 \times 4 = 160\ 5$ ft, $= E$.
Elevation of D is $161\ 3 - 2 \times 5 = 160\ 3$ ft, $= E'$
Elevation of K is $\frac{1}{2}(E' + E) = \frac{1}{2}(160\ 5 + 160\ 3) = 160.4$ ft.
Elevation of V is $H = 161\ 3$ ft
Substituting these values in formula **1**,

$$VM = \tfrac{1}{2}(161.3 - 160\ 4) = 45 \text{ ft}$$

Since, for the first stake, $Ca = 50$ ft and $CV = 200$ ft., formula **2** gives

$$a\,m = \left(\frac{50}{200}\right)^2 \times VM = \frac{1}{16} \times .45 = 03 \text{ ft.} = a'\,m'$$

Similarly, $$b\,m = \left(\frac{100}{200}\right)^2 \times VM = \frac{1}{4} \times 45 = 11 = b'\,m'$$

$$c\,m = \left(\frac{150}{200}\right)^2 \times VM = \frac{9}{16} \times 45 = 25 = c'\,m'$$

The original and corrected grade elevations are as follows

Station	188	+50	189	+50	190	+50	191	+50	192
Original elevation	160 5	160 70	160 90	161 10	161 30	161 05	160 80	160 55	160 30
Correction	0	03	11	25	45	25	11	03	00
Corrected elevat'n	160 50	160 67	160 79	160 85	160 85	160 80	160 69	160 52	160 30

EXAMPLE FOR PRACTICE

Find the corrections in grade and the corrected elevations at stakes 50 feet apart, if the vertical curve is 400 feet long grade of $CV = +4$ per cent, of $VD = -6$ per cent, elevation of $V = 101\ 4$ feet

Ans. { Corrections in grade 00, 03, 13, .28, 50, 28, 13, 03, and 00
Corrected elevations 100 60, 100 77, 100 87, 100 92, 100 90, 100 82, 100 67, 100 47, and 100 20 }

99. Vertical Curve at a Sag.—If two grade lines, $A\,V$ and VB, Fig 28, meet so as to form a sag, the vertical curve will evidently be wholly above both grade lines. Using the notation of the last article, the elevation of K will be $TK = \frac{1}{2}(E + E')$, as before, and the elevation of M,

$TM = \frac{1}{2}\left(H + \frac{E + E'}{2}\right)$. But in this case M is above V, and therefore the correction VM in grade will equal $TM - TV$; that is,

$$VM = \frac{1}{2}\left(H - \frac{E + E'}{2}\right) - H = \frac{1}{2}\left(\frac{E' + E}{2} - H\right)$$

The correction in grade at any point a will be given by formula **2**, Art. **98**, as before, but this correction is now to

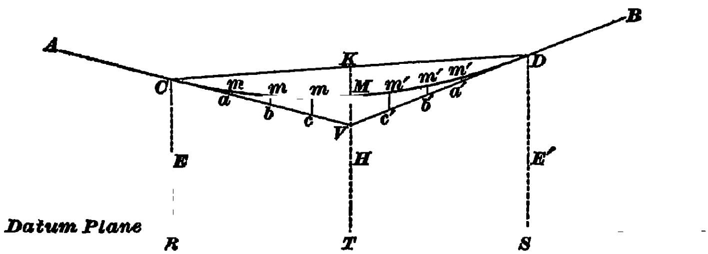


FIG 28

be added to the old grade at a to obtain the corrected elevation.

EXAMPLE —The grade of CV, Fig. 28, is $-1\ 2$ per cent, that of VD is $+.6$ per cent, and the elevation of V is $+49\ 2$ feet To find the corrections in grade and the corrected elevations at stakes 100 feet apart, if the length of the vertical curve is 600 feet

SOLUTION —The uncorrected grades are as follows:

ALONG CV	ALONG VD
At first stake, 52.8	At fifth stake, 49 8
At second stake, 51 6	At sixth stake, 50 4
At third stake, 50 4	At seventh stake, D, 51.0
At fourth stake, V, 49 2	

Therefore, $\frac{1}{2}(E + E') = \frac{1}{2}(52.8 + 51.0) = 51.9$

And, by the formula of this article,

$$VM = \frac{1}{2}(51\ 9 - 49\ 2) = 1\ 35 \text{ ft.}$$

Formula **2**, Art **98**, may now be applied.

Correction in grade at first stake,

100 ft. from $C = \left(\frac{100}{300}\right)^2 \times 1\ 35 = \frac{1}{9} \times 1\ 35 = .15 =$ **correction at fifth stake**

Correction at second stake,

$\left(\frac{200}{300}\right)^2 \times 1.35 = \frac{4}{9} \times 1\ 35 = .60 =$ correction at fourth stake

The corrected elevations will be

At C	52 80	+	.00	= 52 80
At second stake	51 60	+	15	= 51 75
At third stake	50 40	+	60	= 51 00
At fourth stake	49 20	+	1 35	= 50 55
At fifth stake	49 80	+	60	= 50 40
At sixth stake	50 40	+	15	= 50 55
At D	51.00	+	.00	= 51 00

EXAMPLE FOR PRACTICE

Find the corrections in grade and the corrected elevations at stakes 100 feet apart if the vertical curve is 600 feet long Grade of $CV = -1$ 6 per cent , of $VD = +$ 2 per cent , elevation of $V =$ 128 66 feet.

Ans. { Corrections in grade 00, 15, 60, 1 35, 60, .15, and .00
Corrected elevations: 133 46, 132 01, 130 86, 130 01, 129.46, 129 21, and 129 26

100. Table for Vertical Curves.—Table II gives the corrections in grade, am, bm, etc , Figs 27 and 28, for various gradients and lengths of vertical curves The first column contains the total change in the rate of grade G at the angle V. If both grades are ascending [Fig 26 (b)] or both grades descending [Fig. 25 (b)], the change in the rate of grade is evidently the difference of the two rates If one grade is ascending and the other descending [Figs 25 (a), 26 (a), 27, and 28], the change in the rate of grade is the sum of the two rates.

Opposite each value of G in the first column, there are given the corrections in grade at stakes 0, 50, 100, etc. feet from C These corrections are also to be applied to the corresponding stakes distant 0, 50, 100, etc feet from D. The table assumes that a 400-foot curve will be used where G is less than 1 1, a 600-foot curve where G lies between 1.0 and 1 9, and an 800-foot curve for higher values of G.

EXAMPLE —To solve the examples of Arts **98** and **99** by means of Table II

SOLUTION —In the example of Art **98**, $G = 4 + 5 = 9$ In Table II, opposite the value 9 under G are found the corrections, 00, .03, 11, 25, and 45 The solution is now completed as before

TABLE II

CORRECTIONS IN GRADE FOR VERTICAL CURVES

G	Whole Length of Vertical Curve	Distance From Beginning or End of Curve								
		0	50	100	150	200	250	300	350	400
.3	400 feet	0	.01	.04	.08	.15				
.4		0	.01	05	.11	.20				
.5		0	.02	.06	.14	.25				
.6		0	.02	.08	.17	.30				
.7		0	.02	09	20	35				
.8		0	.03	.10	.23	40				
.9		0	03	.11	.25	.45				
1.0		0	.03	.13	.28	.50				
1.1	600 feet	0	.02	.09	.21	.37	.57	.83		
1.2		0	.03	10	.23	.40	.63	.90		
1.3		0	.03	11	.24	.44	.67	.98		
1.4		0	.03	.12	.26	.47	.73	1.05		
1.5		0	.03	.13	.28	.50	.78	1.13		
1.6		0	.03	.13	30	.53	.83	1.20		
1.7		0	.04	.14	.32	57	.89	1.28		
1.8		0	.04	.15	.34	60	.94	1.35		
1.9	800 feet	0	.03	.12	27	.48	.74	1 07	1.46	1.90
2.0		0	.03	.13	28	.50	.78	1 13	1.53	2 00
2.1		0	.03	.13	.30	.53	.82	1.18	1 61	2.10
2.2		0	.03	.14	.31	.55	.86	1 24	1.68	2.20
2.3		0	.04	.14	.32	.58	.90	1 29	1.76	2.30
2.4		0	.04	.15	.34	.60	.94	1.35	1.84	2.40
2.5		0	.04	.16	.35	.63	97	1 41	1 91	2.50
2.6		0	04	.16	.37	65	1 02	1 46	1 99	2.60

In the example of Art **99**, $G = 1\ 2 + 6 = 1\ 8$. In Table II, opposite the value 1 8 of G, are found the corrections, .00, 15, .60, and 1.35 The solution is completed as before.

EXAMPLE FOR PRACTICE

Solve the examples for practice in Arts **98** and **99** by means of Table II

101. Selection of Length for a Vertical Curve. Theoretically, the length of a vertical curve depends on the length of the longest train that is to pass over the curve, and also on the whole change of gradient G (Art. **100**). A simple theoretical formula is

$$\text{Length} = G \times \text{longest train}$$

Thus, if the length of the longest train is 800 feet, and the whole change of gradient is 1.9 per cent, the length of the vertical curve should be $800 \times 1\ 9 = 1{,}520$ feet. Practically, however, so long curves are not inserted. Many roads use the uniform length of 400 feet for all vertical curves If any difference is made, the curves should be longer on a sag than on a spur, for the shock to the roadbed and rolling stock that arises from suddenly changing a rapid downward motion of a heavy train into an upward motion is very great. The length obtained from Table II will be found amply sufficient for any curve that is at a sag, at a spur, the curve may be taken 200 feet shorter than the table indicates, provided that the whole length is never reduced to less than 400 feet.

TRESTLES

INTRODUCTION

1. Definition.—A **wooden trestle,** as considered in railroad work, is a structure intended to carry one or more railroad tracks at an elevation of about 5 feet or more above the natural surface of the ground. Trestles are used as substitutes for earth embankments, either temporarily or permanently.

2. Extent of Trestling.—It was estimated in 1889 that there was in the United States about 2,400 miles of railroad trestle (single track) in a total railroad mileage of about 160,000 miles At the present time (1907), the railroad mileage is considerably in excess of 200,000 miles. At the same rate (1.5 per cent), this would mean that there is at present about 3,000 miles of railroad trestling. It is very probable that the percentage has been reduced, since trestles are often built merely as temporary structures, and the recent years of prosperity have enabled many railroads to replace much of their trestling with permanent earth embankments or with viaducts of metal or stone. In spite of all these substitutions, however, it is still true that there are nearly 3,000 miles of wooden trestling. These trestles involve a yearly cost for maintenance that averages one-eighth of the cost of construction. The amount of timber required for this maintenance and for new construction is so great that it engages the very serious attention of the Forestry Department of the United States Government. Therefore, any improvement in the design that will result in an economy of timber is of high financial value.

3. Classification of Trestles.—Trestles may be classified into permanent trestles and temporary trestles They are further subclassified according to their construction and use. They are permanent when they cross a shallow but wide waterway, or where for any reason an embankment is not permissible. Temporary trestles are generally built when it is necessary to open the road for traffic very quickly, and also to replace a structure that has been destroyed by accident.

Wooden trestles may be divided, according to their methods of construction, into two general classes; namely, **pile trestles,** in which the bents consist of piles united by a cap, and **framed trestles,** in which the bents consist of squared timber members framed together.

A trestle **bent** is a combination of timbers that supports the floor system of the trestle, the bents being spaced at regular intervals—usually about 15 feet.

4. Comparative Cost of Trestles and Embankments.—The height at which it becomes more economical to use trestling than embankment varies widely, depending on the locality, the cost of timber and labor, and the character of material available for making the fill There are, of course, many situations, such as deep swamps or waterways, where an embankment is not practicable. The only question then is to choose between a wooden and an iron structure.

Table I shows the approximate relative cost of embankment and trestle in sections of 100 feet, excluding rails, ties, and ballast on the former, and rails, guard-rails, and ties on the latter. As will be observed, the cost of an embankment increases in a vastly greater ratio than its height; while, on the other hand, the cost of trestling does not increase nearly so rapidly as the height, especially for heights under 50 feet. In comparing the cost of a trestle with that of an embankment, it must be remembered that a culvert will be required under the latter, and its cost must be considered.

TABLE I

APPROXIMATE RELATIVE COST (IN DOLLARS) OF EMBANKMENTS AND TRESTLES

Height From Surface of Ground to Grade (Subgrade) Feet	Cost of Embankment 100 Feet Long, Roadbed 14 Feet Wide, Slope $1\frac{1}{2}$ to 1					Cost of Trestle 100 Feet Long					
						Pile Trestle Having an Average Penetration of 10 Feet, Cost of Piling, in Place, 35 Cents per Lineal Foot			Framed Trestle		
	Width of Embankment at Base	Cost per Cubic Yard, in Cents				Cost of Timber (Including Iron) per M, B M.*					
	Feet	16	18	20	22	$30	$35	$40	$30	$35	$40
5	29	64	72	80	88	376	407	439	283	330	378
10	44	113	127	141	155	441	476	512	385	449	514
15	59	325	366	406	447	508	544	580	464	541	618
20	74	521	587	652	718	576	613	651	541	631	721
25	89	764	859	955	1,050	748	803	858	796	928	1,060
30	104	1,049	1,180	1,312	1,443	816	872	928	872	1,017	1,163
35	119	1,380	1,552	1,725	1,897	990	1,065	1,140	1,058	1,234	1,410
40	134	1,754	1,974	2,193	2,412	1,057	1,132	1,218	1,133	1,322	1,510
45	149	2,174	2,446	2,717	2,989				1,202	1,404	1,606

*The expression *per M, B M* means *per thousand feet, board measure*

Table II gives the cost of pile and framed trestles complete, including floor systems, for heights from 5 to 45 feet, inclusive, in sections of 100 feet.

TABLE II

COST (IN DOLLARS) OF PILE AND FRAMED TRESTLES

Height Feet	Pile			Framed		
	$30	$35	$40	$30	$35	$40
5	546	605	665	453	528	604
10	611	674	738	555	647	740
15	678	742	806	634	739	844
20	746	811	877	711	829	947
25	918	1,001	1,084	966	1,126	1,286
30	986	1,070	1,154	1,042	1,215	1,389
35	1,160	1,263	1,366	1,228	1,432	1,636
40	1,227	1,332	1,444	1,303	1,520	1,736
45				1,372	1,602	1,832

The cost of timber work complete and the cost of earthwork are so variable that even Tables I and II do not have a sufficient range to cover all cases; but the figures given are valuable as a general guide in making comparative and preliminary estimates.

When using Table I, it must not be forgotten that the cost of the culvert under the embankment depends on its size and type of construction; the length of the culvert is of course somewhat less than the width of the embankment at its base. Adding the cost of the culvert to that of the embankment will lower the height at which the embankment becomes more expensive than the trestle.

5. Technical Terms.—The various technical terms used in trestle work will now be defined and illustrated The diagrams given throughout this Section should be studied for further and perhaps clearer illustrations of the various parts of a trestle.

Bents are of two kinds; namely, framed bents and pile bents. A **framed bent** (*1*, Fig. 1; also shown in Figs. 69 and 70) is a frame of timbers that rests on an independent

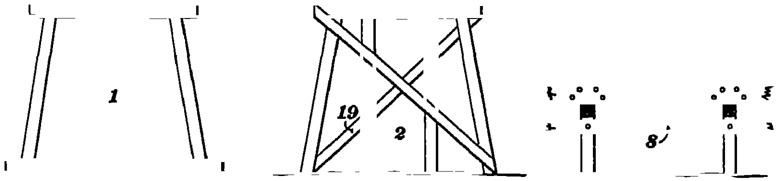


FIG 1

foundation and supports the floor system. A **pile bent** (*2*, Fig. 1; also shown in Fig. 71), is a support for a trestle floor system; this bent consists essentially of piles driven ver-

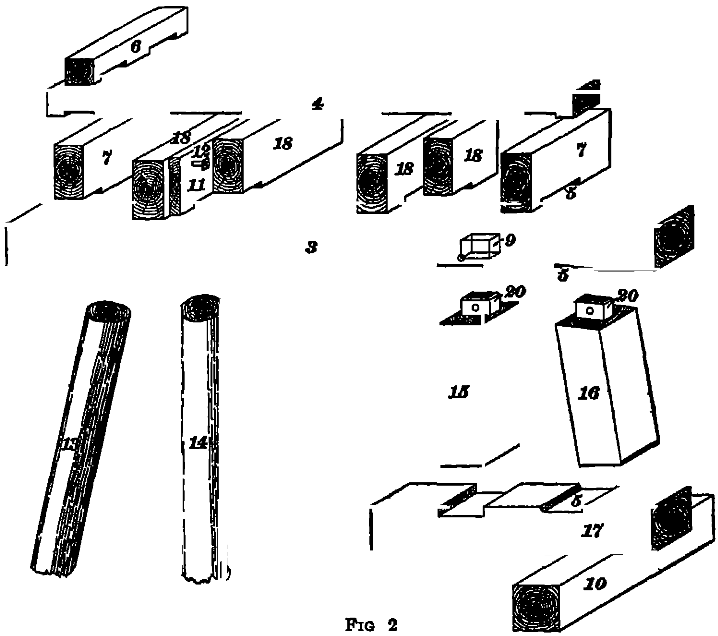


FIG 2

tically, or nearly so, the piles being topped with a cap and if necessary, stiffened with cross-bracing

The **cap** (*3*, Fig. 2) is the cross-timber at the top of the posts.

The **cross-tie** (*4*, Fig. 2) is the special form of tie used for trestles.

Dapping (*5*, Fig. 2) is the name given to a groove cut in a timber member for rendering it more secure against slipping out of place. **Gaining** or **notching** is used in the same sense as the term *dapping.*

A **guard-rail** (*6*, Fig. 2) is a timber laid on the ties and perpendicular to them, for the double purpose of keeping the ties in place and of preventing a derailed car wheel from rolling off the trestle floor.

A **jack-stringer** (*7*, Fig. 2) is a stringer placed immediately under the guard-rail.

A **longitudinal brace** (*8*, Fig. 1) is a timber brace that runs longitudinally with the length of the trestle and braces adjacent trestle bents.

A **mortise** (*9*, Fig. 2) is a hollow cut into a timber to receive the tenon on the end of a post.

A **mud-sill** (*10*, Fig. 2) is one of a series of timbers sometimes used as the foundation for a framed trestle, the timbers being laid perpendicular to the sill of the trestle bent

A **packing-block** (*11*, Fig. 2) is a strip of timber – usually about 2 inches thick, 12 inches wide, and 5 or 6 feet long —laid between parallel stringers and bolted to them.

Packing-bolts (*12*, Fig 2) are the bolts that fasten the stringers and packing-blocks into a compact structure.

Piles.—Piles that do not run vertically are said to be **battered, inclined,** or **braced** (*13*, Fig 2). If used at all, they are placed at the ends of pile bents. **Vertical, plumb,** or **upright** piles (*14*, Fig 2) are piles driven vertically.

Posts.—The posts of a framed trestle bent that are not vertical are said to be **battered** or **inclined** (*16*, Fig. 2) When used, they are placed at the ends of the trestle bent. **Vertical, plumb,** or **upright** posts (*15*, Fig. 2) are the vertical posts of a framed trestle bent.

The **sill** (*17*, Fig. 2) is the cross-timber on which the posts of a framed trestle bent rest, corresponding with the cap at the top.

A **stringer** (*18*, Fig. 2) is one of several timbers connecting adjacent trestle bents and forming the main supporting timbers of the floor system.

A **sway-brace** (*19*, Fig. 1) is a comparatively light timber used on each side of a framed or pile trestle bent to stiffen the bent against lateral distortion.

A **tenon** (*20*, Fig 2) is the projection on the end of a post which fits into the mortise.

A **treenail** is a wooden nail, usually made of hard wood, driven through the mortise and tenon [see Fig 8 (*b*)].

Waling Strip.—See longitudinal brace *8*, Fig. 1.

BENTS

PILE BENTS

6. General Considerations.—Where the height of a trestle bent does not exceed 30 feet, and where the ground is soft and marshy, so that a suitable foundation is difficult to obtain, pile trestle bents are frequently used, since they are constructed rapidly, and the driving of the piles serves the double purpose of constructing the bent and also its foundation The main disadvantage of pile bents is that the piles, being subject to alternations of wetness and dryness near the surface of the ground, decay rapidly. When pile bents are used for greater heights than 30 feet, only a comparatively small part of the piles penetrates the ground, and though they may reach a substantial bottom, the bent is weak, owing to the small diameter of the pile and the small proportion of heart timber at the top of the tree. It is the heart timber alone that can long resist decay, and at the surface of the ground, where the timber is alternately wet and dry, decay sets in as soon as the structure is erected, and in a few years, at best, the piles must be renewed, though the remainder of the trestle may be in a comparatively sound condition.

7. Piles.—The subject of piles, pile driving, and pile foundations is fully treated in *Foundations*, Part 2, so that here it will be sufficient to consider only that part of the subject which is peculiar to trestle work. Piles should be cut from live, straight, thrifty trees, free from dead or loose knots, wind shakes, and all signs of decay. They should have a butt diameter of from 12 to 15 inches, and a top diameter of from 7 to 10 inches inside the bark. *Squared piles*, which are used in a limited way, should measure 12 inches square at the butt and not show more than 2 inches of sap wood on the corners. It is the custom on some railroads to paint the pile for a short distance above and below the ground line with hot tar, in order to retard decay.

Timber suitable for piles may be found in most sections of the United States. The different varieties of timber commonly used for piling are named in the following list in the order of their suitability:

red cedar	white pine	white oak
black cypress	redwood	post oak
pitch pine	elm	tamarack
yellow pine (long-leaf)	spruce	hemlock

8. Construction of Pile Bents.—The spacing of the piles forming the bent varies considerably, with different constructors, though the general arrangement is the same.

For a height of bent not exceeding 5 feet, and where the railroad is to carry only a moderate traffic, a three-pile bent is generally adopted, one pile being placed directly on the center line and the others spaced from 3 feet 6 inches to 5 feet out, the piles being driven vertically (see Fig. 3). For trunk lines, however, whatever the height, all bents should contain at least four piles.

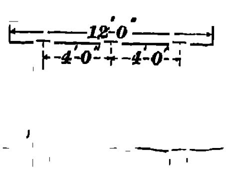


Fig. 3

For heights of from 5 to 15 feet, each bent should contain four piles driven vertically. The inner piles may be spaced from 4 to 5 feet, and the outer ones about 11 feet from center to center (see Fig. 4). Pile bents of this height

do not strictly require sway-bracing, provided that the penetration amounts to 6 or 8 feet in firm earth; it is the best

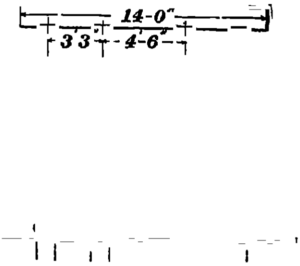


FIG 4

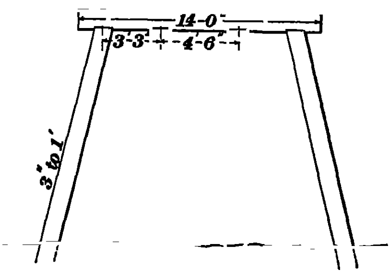


FIG 5

practice, however, to provide sway-bracing on all bents. For heights exceeding 15 feet, it is well to batter the outside piles, as shown in Fig. 5. By this means, the width of the base and therefore the stability of the structure is considerably increased. Piles are battered from 2 to 4 inches to the foot, 3 inches being commonly adopted. Where the diameter of the pile at the cut-off point exceeds the width of the cap, the part of the pile that projects should be adzed off at an angle of 45°, as shown in Fig. 6.

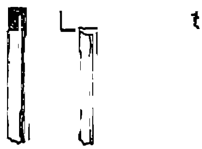


FIG 6

9. Capping and Cutting Off.—When a floating pile driver is used, the sawing off and capping of the piles may follow the driving, at the convenience of the contractor, though it is better to follow the driving closely with the

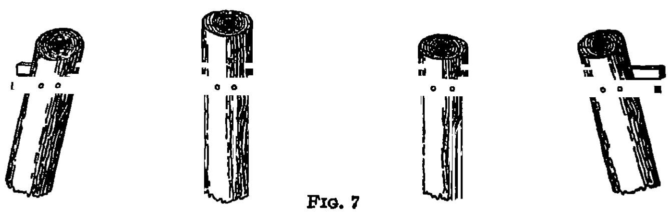
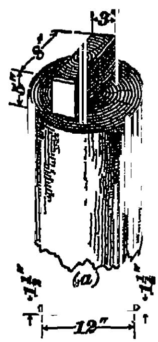


FIG. 7

caps and stringers When a pile driver mounted on a car is used, each bent must be cut off and capped and the timbers laid before the driver can advance to the next bent.

As soon as a bent of piles is ready for cutting off, the height of the top of pile is given and a narrow, straight-edged strip of board (ordinary roofing lath serves well) is nailed on each side of the bent with its top edge at the proper height for cutting off (see Fig. 7). The cutting off is best done with a cross-cut saw worked by two men. If the piles are tenoned to the caps, the cutting necessary to form the tenon is done with the cross-cut saw

10. Caps may be fastened to the piles in three ways; namely, by mortise and tenon, by drift bolts, or by dowels. For solid caps, a tenon 3 inches thick, 8 inches wide, and 5 inches long is a good size [see Fig. 8 (*a*)]. The top edges of the tenon should be chamfered and the mortise and tenon made so as to fit snugly. The parts are held together by means of treenails. Treenails are from 1 inch to 1½ inches in diameter, and slightly tapering [see Fig. 8 (*b*)]. They should be made of hard wood, oak or locust being preferable. The hole made in the cap to receive the pin should be spaced a little farther from the base of the cap than the hole in the tenon from the tenon shoulder, so that, in driving the pin, the parts will be drawn together Iron bolts or pins should never be used in place of wooden pins. Instead of crowding or drawing the parts together, the iron punches or cuts away any wood that lies in its path, merely increasing the size of the hole.



(b)
FIG. 8

11. When drift bolts or dowels are used, the piles are cut off level, and holes are bored in both cap and pile to receive the drift bolt or dowel. Sometimes two drift bolts or dowels are used at each pile, but commonly only one, which is sufficient. A hole is first bored through the cap into the pile head to receive the drift bolt, which should be somewhat larger than the hole, so that, in driving it, every cavity in the hole may be completely filled (see Fig. 9).

12. Dowels are of shorter length than drift bolts and extend only about half way through the caps (see Fig. 10). To drive dowels, they are first driven for about half their length into holes that have been bored in the tops of the piles to the proper depth These holes should be exactly in line. Then, a series of holes are bored in the cap exactly in line and at corresponding distances apart The cap is then placed over the dowels so that each dowel will enter its hole. The tops of the piles may be forced over to allow for a slight error of boring. The cap is then hammered down into place.

Another method of fastening caps to piles, and one that is rapidly growing in favor, is by means of split caps, shown in Fig. 11, in which the cap, instead of being a single piece of timber, consists of two pieces, each half the size of the

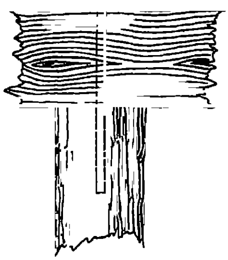


FIG 9

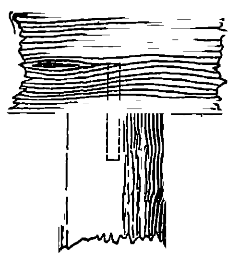


FIG 10

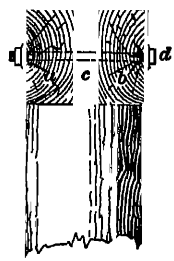


FIG. 11

single piece. For example, instead of using for the cap a single stick of timber, 12 in. × 12 in., as shown in Figs. 9 and 10, two pieces *a* and *b*, Fig 11, each 6 in. × 12 in., are substituted. A tenon *c*, 3 inches wide and extending the full width of the pile, is formed at its top, and a cap is placed on each shoulder against the tenon A $\frac{3}{4}$-inch bolt *d* is passed through the caps and tenon, and holds them firmly in place. The caps should not be notched, and the piles should be sawed off smooth and level so as to afford a good bearing for the caps.

Some of the advantages claimed for split caps are the following.

1. On account of the smaller size, better timber can be obtained at less cost.

2. Repairs can be made with ease and great economy of time and labor.

3. Traffic need not be interrupted nor endangered while repairs are being made.

4. The caps may be replaced without cutting or injuring any other part of the structure.

5. There is some economy in material, because, unless both sticks are decayed, it is not necessary to replace the whole cap, but only that part which is no longer in a serviceable condition.

FRAMED BENTS

FOUNDATIONS

13. Framed bents are composed entirely of sawed timber, and are placed on a foundation, the objects of which are to insure stability to the structure and, by raising it from the ground, to prolong its life. All timber placed in direct contact with the ground partakes of all its changing conditions of drouth and moisture, which soon induce decay. Among the various kinds of foundations used for trestle bents are the following: *masonry*, *pile*, *sub-sill*, *grillage*, *crib*, *solid rock*, and *loose rock*.

14. Masonry foundations are the best. They are ordinarily composed of rubble masonry laid in cement mortar. Good forms of masonry foundations are shown in

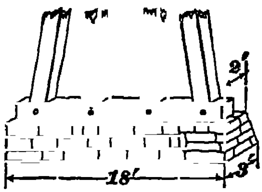


Fig 12

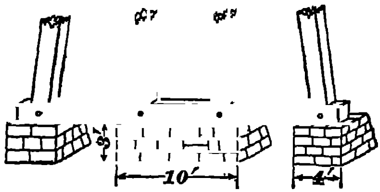


Fig 13

Figs. 12 and 13. In northern latitudes, trenches at least 2 feet in depth should be excavated for these foundations to prevent them from being heaved by hard freezing. In

exposed localities where the freezing is very severe, it may be necessary to excavate the foundation trenches to a depth of 3 feet.

It is bad practice to use irregularly shaped stone, especially cobblestone, in building trestle foundations. The continual jar caused by passing trains is likely to injure seriously masonry of an inferior quality. Dry rubble, if built of long stones with horizontal beds, and well bonded, is far superior to mortar rubble of poor quality. The foundation walls shown in Figs. 12 and 13 are supposed to be laid in foundation pits 2 feet deep, and to extend 1 foot above the surface of the ground. The ends of the wall should be vertical, and the sides battered about 2 inches to the foot.

15. Pile Foundations.—When pile foundations are employed for marshy ground that is not too deep, it is a good plan to allow the piles to extend far enough above the surface of the ground to form a bent, which is capped and a framed bent placed on top of it Where the trestle crosses a waterway, it is good practice to place a framed bent on a pile foundation of such height as to remain always under water. The decay due to alternate wetting and drying is thus confined to the framed portion, which can easily be renewed.

16. Sub-sills or mud-sills are blocks of timber placed under the main sills to raise them above the ground to prevent decay and to distribute the pressure over a greater area.

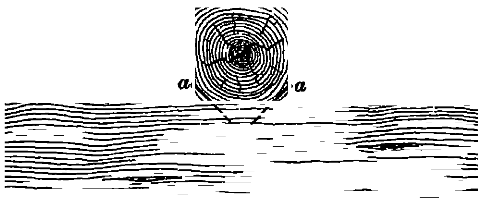


FIG 14

Some recommend plank 3 or 4 inches thick, but 12″ × 12″ timber is far better, and the additional cost is trifling compared with the solidity of foundation and security against

decay. The sills and sub-sills should be fastened together, to prevent the latter from being displaced. As the strain is slight, 6-inch cut spikes, driven as shown at *a*, *a*, Fig. 14, will serve for a fastening.

17. Grillage.—Grillage is defined, and the general method of construction illustrated, in *Foundations*, Part 2. It is used as the foundation for trestles when the soil is so soft that a large area for the foundation is necessary. Placing the timbers at a distance apart of two or three diameters has virtually the same effect as a continuous foundation

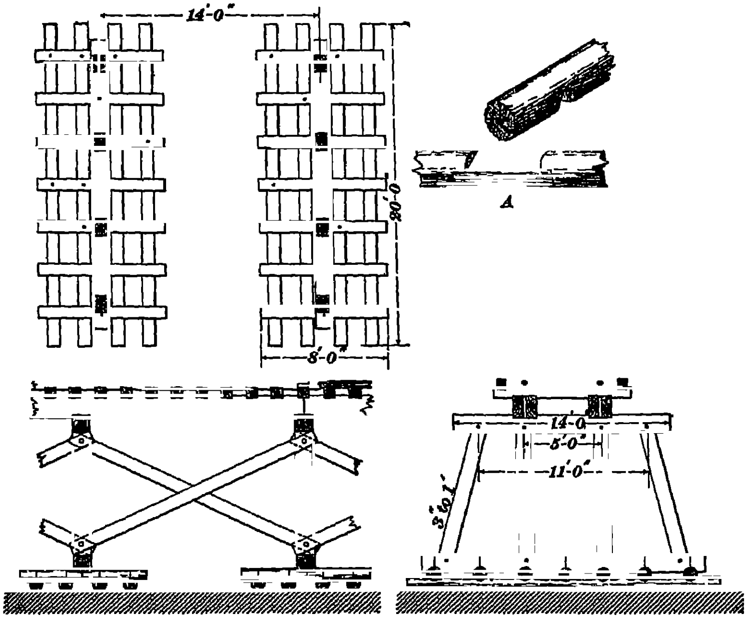


FIG. 15

with the same gross area, but the economy of material is very great. Generally, the grillage timbers are round trunks of trees; such timber serves its purpose well and is, perhaps, more durable than solid timber, besides being cheaper. The timbers are usually notched at each intersection, as shown in detail at *A*, Fig. 15, and should be drift-bolted at the

intersections The tops of the cross-logs are adzed to a common level to receive the sills of the trestle bents, which are drift-bolted to the grillage. The grillage shown in Fig. 15 was employed in the Northern Adirondacks in crossing a subterranean lake. The lake was covered with earth to the depth of several feet and overgrown with brush and timber, but was unsafe for an embankment. The longest piles failed to reach bottom. By means of this grillage, the weight of the trestle and train load was distributed over such an area that it could be safely carried. Although the road has been in operation for many years, no considerable settlement has taken place

18. **Cribs.**—A **crib** is a framework of timber designed to be weighted down by means of a filling of stone or earth. Ordinarily, cribs are made somewhat in skeleton form; that is, so that the timbers are spaced several inches apart. This economizes timber, and does not interfere with the necessary strength. Crib foundations have the advantage of

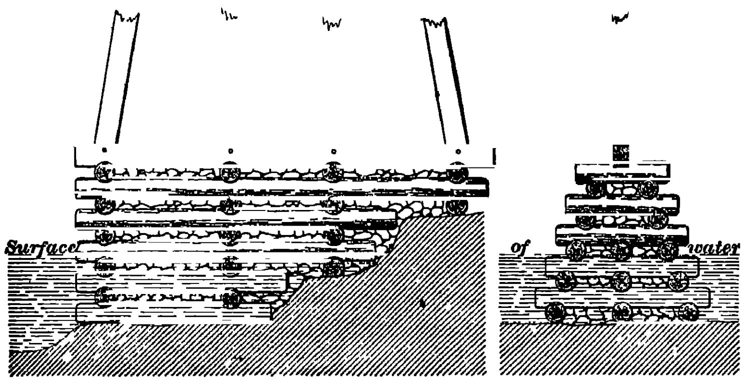


Fig 16

cheapness and rapidity of construction, but lack durability If a trestle crosses a stream and it is necessary to place one of the trestle bents in the stream, such a foundation can be readily constructed and used It is sometimes necessary to locate a line on the very edge of a stream where an embankment would probably be washed away: in such cases, a crib

construction is of great value, since it is so readily constructed and will not be washed away by a swift current. An illustration of such a foundation is shown in Fig. 16 It will be observed that the bottom of the crib can be so made as to adapt it to an irregular or uneven bottom.

19. Pile Bents on Solid Rock.—If the surface is solid rock, all that is necessary in preparing a foundation is to smooth off a place for each post to stand on. The readiest way to fasten each post is by means of a dowel, which should reach 5 or 6 inches into the rock and an equal distance into the post. In some instances, holes are blasted into the surface rock and the posts stood in the holes. After the posts are fastened together to form a bent, the vacant space about the foot of each post is filled with rich cement mortar. When such foundations are used, the system of bracing should be ample, especially where the trestle is built on a side hill, which requires posts of much greater length on the lower than on the upper side.

20. Loose Rock.—Where masonry would prove too costly, satisfactory foundations may be constructed of loose rock. Foundations of this character are made by first

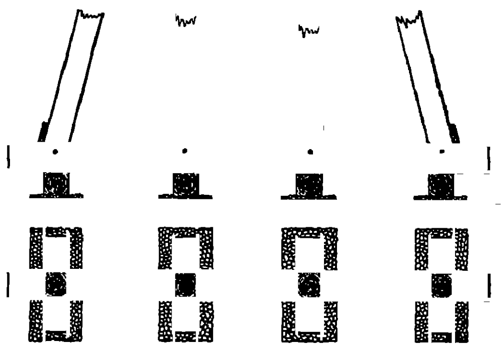


FIG. 17

excavating a short trench directly under each post, as shown in Fig. 17, and then filling the trenches with broken stone, on which sub-sills are placed to form the supports for the sills. If water accumulates in the trenches, it may

be drained off by digging around the foundations shallow open ditches and leading them away to lower ground. This will at least save the sub-sills from contact with water and so preserve them from rapid decay.

21. Drip Holes. –The tendency of water to accumulate in mortises hastens decay of the timbers. To prevent this, every mortise forming a receptacle for water should be provided with a drip hole ½ inch in diameter bored with a downward inclination from the bottom of the mortise to the outside of the timber. Two methods of boring drip holes are shown in Figs. 18 and 19. In Fig. 18, the drip hole *a* leads vertically downwards from the mortise, in Fig. 19, the hole *b* is inclined downwards to the side of the sill.

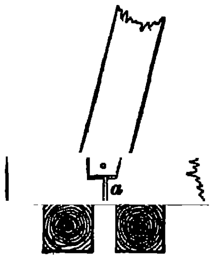


FIG 18

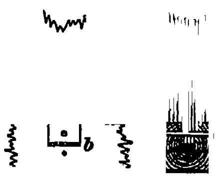


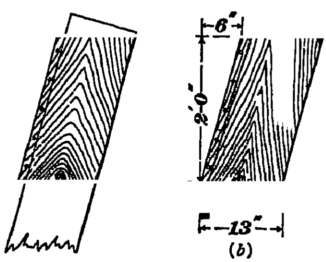
FIG 19

DETAILS OF CONSTRUCTION

22. Posts.—There are usually four posts to a bent: two vertical, or plumb, posts; and two inclined, or batter, posts. The standard dimensions of trestle posts are 12 in. × 12 in., though other dimensions are sometimes used. The plumb-posts should be spaced from 4 to 5 feet between centers, and the batter posts 11 feet from center to center at the top. The inclined posts should have a batter of 3 inches to the foot. This gives a broad base, adding considerably to the stiffness and stability of the structure. It is poor economy to stint the dimensions.

23. Framing Batter Posts.—It is very important that the upper and lower ends of the batter posts should be cut off at precisely the proper angle, so that when they are placed in position the surfaces may fit the cap and sill. When a large number of posts must be framed with the

same batter, the simplest plan is to make a **templet.** Such a templet is illustrated in Fig. 20 (*b*), the batter being 1 horizontal to 4 vertical. A piece of ½-inch hardwood board is cut to the proper inclination (in this case 1 : 4, or 6 inches to 2 feet), and a 1-inch cleat is fastened to the edge of the board. A piece of timber a little longer than the distance between the extreme corners at each end may then be cut to the exact length by placing the templet on the post, as illustrated in Fig. 20 (*a*). In this case, the templet becomes merely a modified form of T square, the cleat corresponding to the head of the square. The upper and the lower edge should be exactly parallel. The upper and the lower end of the post may be marked by simply sliding the templet along one edge of the post, the upper edge serving for the top cut and the lower edge for the lower cut.



(a) FIG. 20

One method of framing the posts to the cap is illustrated in Fig. 21. The method has the doubtful advantage of economy, since each batter post and its corresponding vertical post are framed into one large mortise instead of into separate mortises. Another method of construction is that illustrated in Fig. 22, in which all the posts are battered. In this case, the outer posts have a uniform batter, and therefore the length of the sill varies directly as the height of the trestle. The inner posts change their batter with each change of height. It is very questionable whether the variation for


FIG 21

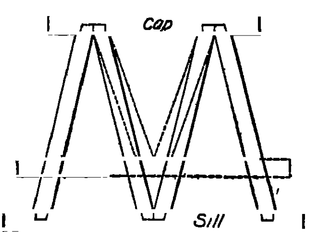


FIG 22

each height does not produce more labor and liability to error in the framing than would result from adopting a batter such as the inner posts would need for the highest trestle to be constructed, and then using this batter uniformly for all inner posts This would separate the bases of the inner posts for the lower trestles.

24. Caps.—If solid, caps should be of not more than 12″ × 12″ timber, while, in a majority of cases, 10″ × 10″ stuff would serve equally well, frequently assuring better material as well as effecting a considerable economy. There are several ways of joining the sills, posts, and caps together, but only three are in general use; namely, by mortise and tenon, by drift bolts, and by dowels. These have already been described.

A tenon (see *20*, Fig. 2) 3 inches thick, 8 inches wide, and 5 inches long is a good size. The mortise should be about ½ inch deeper than the length of the tenon, and well finished, so that the tenon will fit snugly. In boring the hole for the treenail, the same precaution should be taken with framed bents as with pile bents (see Art. **10**). All mortises so placed as to hold water should be provided with drip holes.

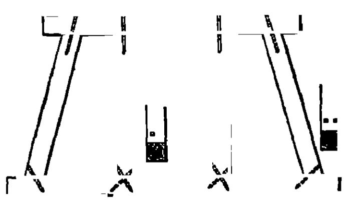


FIG 23

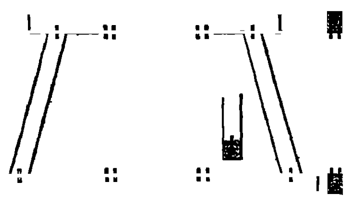


FIG 24

The use of drift bolts in connecting cap and sill with post is shown in Fig. 23, and the manner of making dowel connections in Fig. 24.

Two drift bolts are required to fasten a post to the sill, and one in securing it to the cap. A hole must be bored for each drift bolt. The drift bolts used for these connections are either of square or of round iron If square, ¾-inch iron will answer, or iron of equivalent weight, if round. Dowels are usually of ¾-inch round iron.

On some roads, split caps and sills are preferred; when such is the case, the connections with the post are made similar to split-cap connections of pile trestles (see Fig. 11).

Fig 25

Fig 26

It is customary to notch both cap and sill at the post joints. For the battered posts, both beveled and square notches are employed (see Figs. 25 and 26), though the former (Fig. 25) are to be preferred.

25. Distance Between Bents.—Bents should be uniformly spaced, the distance between centers of bents being from 12 to 16 feet, depending on the character and cost of timber. Spans from 12 to 14 feet are most common.

FLOOR SYSTEM AND BRACING

FLOOR SYSTEM

26. Corbels.—A **corbel** is a piece of timber from 8 to 12 inches wide, 10 to 12 inches thick, and about 6 feet long. It is placed under and parallel with the stringers. Its object is to relieve the ends of the stringers from the crushing effect due to the weight of the stringers and their load. When

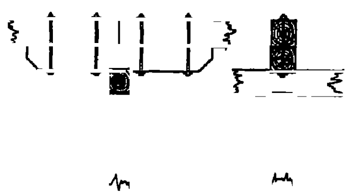


Fig 27

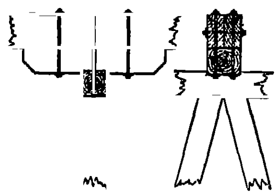


Fig. 28

stringers are made of a soft wood, they are likely to be crushed at the ends where they rest on the caps. A corbel will increase this area five or six times, and thus prevent the stringer from being crushed. Incidentally, the vertical bolts that fasten the corbels to the stringers, as shown in

Figs. 27 and 28, tie the stringers to the corbel, and so bind the stringers together. The corbel is always made of hard wood, as white oak, which can resist crushing more readily than the softer wood that may be used for the stringer. Notwithstanding these advantages, some of the best engineers object to the use of corbels. They certainly make the structure more complicated; and in cases where the stringers can be made of hard wood, corbels are scarcely necessary or advantageous. The corbel should be notched down on to the cap. One effect of the corbel is virtually to shorten the span of the stringers, thereby increasing the strength of the structure.

27. Stringers.—The term **stringer** has already been defined and illustrated in Art. **5** (see also Figs. 39 to 42). One stringer or group of stringers is always placed under each rail Generally, two or more timbers are used, rather than one timber of the requisite cross-section. This is done because it is not always practicable to obtain timbers of large cross-section in a perfectly sound condition; because this method is far less expensive; because the smaller timbers are more easily handled, and because, if one of them decays or is damaged by accident, the other stringers are not necessarily affected. The stringers should be separated by packing-blocks, as will be presently explained.

Wherever practicable, the stringers should be long enough to cover two spans. Then they are made to overlap so that over each cap there is at least one joint and one continuous stringer (see Figs 39 to 42). In order to secure the stringers to the cap, they are sometimes notched on the under side; this prevents any longitudinal motion. If corbels are used, the corbels are notched on the cap and the stringers are bolted to the corbels. To prevent lateral motion, **spreaders** are placed on top of the cap between the stringers. These spreaders are pieces of heavy plank, usually about 3 inches thick, that are spiked to the top of the cap, as shown at *a*, Fig. 29. To prevent the possibility of the floor system being jarred loose from the caps, the stringers are

sometimes bolted to the caps with either screw bolts or drift bolts. The use of drift bolts in this way is very objectionable, as it is practically impossible to withdraw a drift bolt without splitting open the stringer; besides, it is unnecessary, since, if the stringer is secured against longitudinal and lateral motion as described, the weight of the floor system is amply sufficient to prevent any upward motion. The stringers are also stiffened by the ties, which are usually notched on their under side where they rest on stringers. This detail is also shown in Fig. 29.

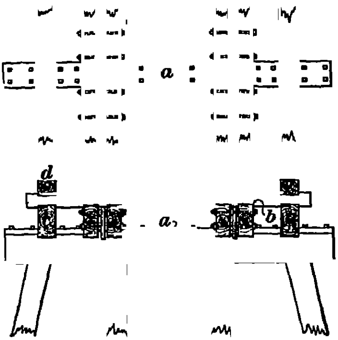


FIG 29

28. Packing-Blocks and Separators.—If two pieces of sawed timber are placed side by side as close as possible, the joint between them will be wide enough to admit water readily, but not wide enough to allow the timber to dry quickly, the result being that the timber will decay in a short time. On this account, it is necessary to separate the stringers by a space of ½ inch or more. This is sometimes done by

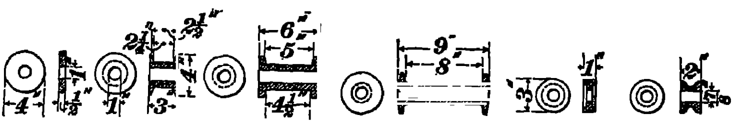


FIG. 30 FIG 31 FIG 32 FIG 33 FIG 34 FIG 35

using cast-iron washers or **separators,** which are essentially rings or spools of cast iron having a hole a little larger than the bolts used to fasten the stringers together, and of a length (parallel to the bolt) that varies between ½ inch and 9 inches. Several forms of cast-iron separators are shown in Figs. 30 to 35.

A **packing-block** is another kind of separator. It is a plank about 2 inches wide and from 4 to 6 feet long.

Packing-blocks are illustrated in Figs. 36 to 38, and, also, in connection with the stringers, in Figs. 39 to 42, which show some of the best of the many styles of stringer joints. As

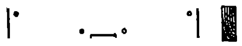


FIG 36

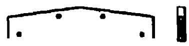


FIG 37

FIG 38

shown in the figures, the packing-blocks serve the additional purpose of scarfs to join the stringers together. Although they are sometimes packed in closely between the stringers, as shown in Fig. 39, it is usual to employ small cast-iron

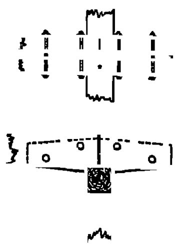


FIG 39

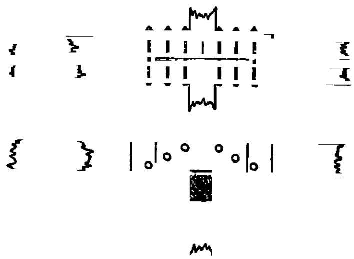


FIG 40

separators even between the stringers and packing-blocks, for the same purpose as just given; namely, to prevent decay between the packing-blocks and the stringers.

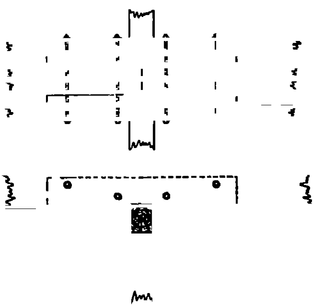


FIG 41

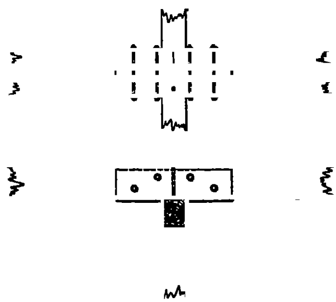


FIG 42

29. Size of Stringers.—The size of stringers depends on the length of the span and the loads that the trestle must carry. When a trestle is very high, it is economical to

lengthen the span between trestle bents so as to reduce their number. On the other hand, a limit of span is very soon reached where stringers acting as beams cannot carry modern train loads. A span of 16 or 18 feet is about the limit, unless special means are used to truss the stringers, in which case the span may be increased to about 25 feet. This plan has the objection that all the stringers must break joints at every trestle bent, or else the stringers must have a length of 50 feet. It is very difficult to obtain stringer timber of the proper cross-section and 50 feet long. Yellow pine is the most commonly used timber for stringers, although white pine, spruce, and oak are used, if they can be obtained readily.

A jack-stringer composed of a single piece of timber, as shown at *c*, Fig. 29, is often placed near the ends of the ties and directly beneath the guard-rail, for the purpose of affording additional support to the ties in case of derailment. Without this support, the ties are likely to be broken by a derailed engine, and a total wreck follow; while, with it, provided that the guard-rail holds, the engine and train are likely to remain on the trestle. The jack-stringers should reach over two spans, and be bolted to the caps.

30. Ties.—Trestle ties vary in both section and length. A $7'' \times 8'' \times 12'$ tie is considered a good size; the length provides for a jack-stringer. Many ties are only 9 feet in length, while others are 10 feet. They are spaced from 12 to 24 inches between centers, although 15 inches should be the limit. The reason for placing them close together is that, in case of derailment, ties closely spaced afford a fairly continuous support for the car wheels, especially the driving wheels, while those widely spaced allow the wheels to drop between and tear up the ties, with the result that a wreck is likely to follow. On some roads, none of the ties are fastened to the stringers; on others, every fifth, or even every other tie is fastened,

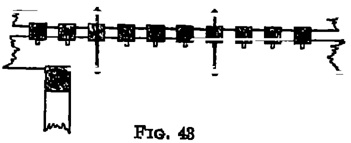


FIG. 43

spikes or lagscrews being generally used for the purpose. Dowels are used for tie-fastenings, but only to a limited extent (see Fig. 43).

Four standard floor systems are given in Figs. 44 to 47, showing the arrangement and mode of fastening cross-ties.

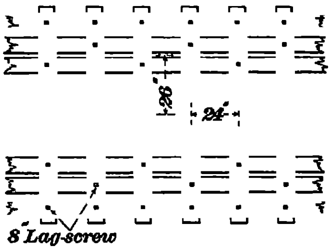


FIG 44

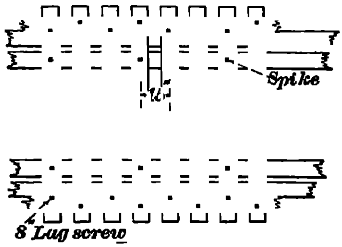


FIG 45

In the Pennsylvania standard, Fig. 44, the wide spaces between the ties are a serious objection, as in case of derailment they render wreck almost certain The dimensions and arrangement of ties in Fig. 45 are especially recom-

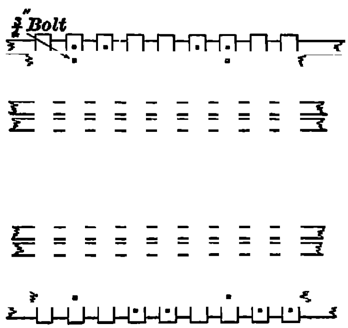


FIG. 46

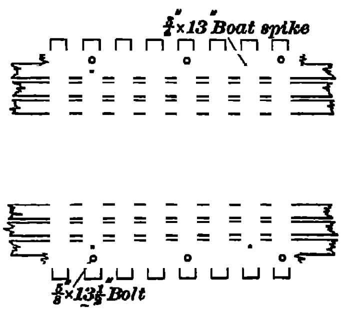


FIG 47

mended. Ties should always be notched down 1 inch over the stringers. Notching prevents any lateral movement and strengthens the floor system.

31. Guard-Rails.—Guard-rails are an important part of the trestle: they serve the purposes of preventing a train from leaving the trestle in case of derailment, of maintaining the spacing of the ties, and of adding weight and

strength to the floor system. Where a jack-stringer is used, the guard-rail is placed directly above it. Guard-rails should be notched down on the ties, usually 1 inch, and fastened to them with either bolts or lagscrews, and should have a section not less than 6 in. × 8 in The length depends on the available supply, but no length under 16 feet should be used. Commonly, the guard-rails and cross-ties are of the same-sized timber, 7 in. × 8 in. being a standard size, the lengths running from 20 to 24 feet.

Guard-rails are spliced in a variety of ways. Various forms of splices are shown in Figs. 48 to 51. The halved joint, Fig. 48, is recommended as simple and effective. Joints should come directly over a tie and be broken, that is a joint on one guard-rail should be on line with the middle point of the opposite guard-rail. Each joint should be fastened with either a bolt or a lagscrew. Bolts are much to be preferred to lagscrews for fastening guard-rails to ties.

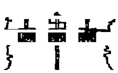


FIG 48

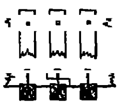


FIG 49

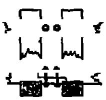


FIG 50


FIG 51


FIG 52


FIG 53

Lagscrews tear the fiber of the wood, and form cavities that hold moisture and induce decay. The best plan is to bolt every fourth or fifth tie to the guard-rail, and spike the remaining ties with 10-inch boat spikes. A punched washer should be put under the head of each lagscrew. It is a waste of time and an injury to the timber to countersink the heads of bolts or lagscrews. The holes form receptacles for water, which soon induces decay. A 3- to 3½-inch cast washer should be placed under the head and nut of each bolt, the nut being placed up so as to make inspection and repairs easy.

32. The ends of the guard-rail should be beveled, as shown in Figs. 52 and 53. The guard-rails should extend from 20 to 30 feet from the trestle on to the embankment. They should be flared outwards so that at their extremities

they will be from 3 to 4 feet from the rails (see Fig. 54). The object of flaring them is to assist in passing the trestle in safety any car that may have been derailed on the embankment. On some roads, in addition to these flaring guards,

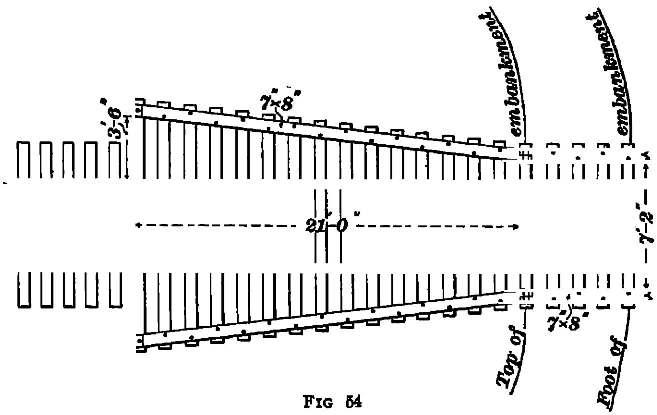


FIG 54

bumping posts are placed near the end of the embankment, but their value is not generally admitted.

An additional safeguard, which is in general use on some lines, is an inner guard-rail of the same section as the main rail, placed $2\frac{1}{2}$ inches inside the rail. Objection is made by some to this form of guard-rail on the ground that it forms a lodgment for detached pieces of the truck, such as brake shoes, box lids, etc., causing the wheels to mount the rails. The tendency of wheels to mount the wooden guards may be prevented by fastening a strip of angle iron on the upper inside edge of the guard-rail.

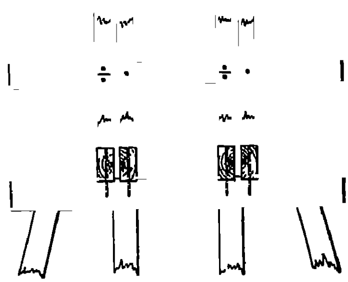


FIG 55

33. Fastening Down the Floor System.—There are several methods of fastening down the floor system to the bents, some of which have already been mentioned. The method generally adopted is to drift-bolt the stringers to

the caps (see Fig. 55). The only objection to this method has already been stated; namely, the difficulty of removing the bolts when making repairs. This mode of fastening the floor system has the merits of simplicity and security, and is more used than any other. Another method is to bolt the stringers to the caps, in which case the posts must be so spaced as to allow the bolt to pass through the cap. On some roads the stringers are not fastened to the caps, the weight of the floor system being depended on to hold them down.

BRACING

34. Sway-Bracing.—Sway-bracing, defined and illustrated in Art. **5**, and further illustrated in Figs. 56 and 57, is used to resist any lateral force, such as wind pressure, that would tend to make the trestle collapse laterally. Pile or framed bents under 10 feet in height seldom require any sway-bracing. Bents from 10 to 20 feet in height require a single **X** brace of 3″ × 10″ plank extending diagonally from the upper corner of the cap to the foot of the opposite pile, or to the outside corner of the sill, in the case of a framed bent (see Fig. 56). For bents from 20 to 40 feet in height, two **X** braces separated by 3″ × 10″ horizontal planks spiked to both sides of the bent, as shown in Fig. 57, afford ample bracing. There are two methods of fastening the sway-braces, both of which are in general use. In one, the sway-braces are fastened to the piles or posts with ¾-inch bolts and cast washers, as shown in Fig. 56; in the

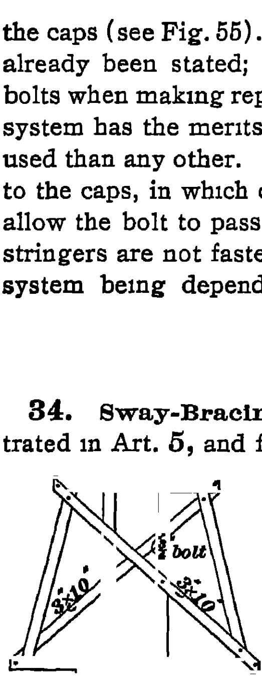


FIG 56

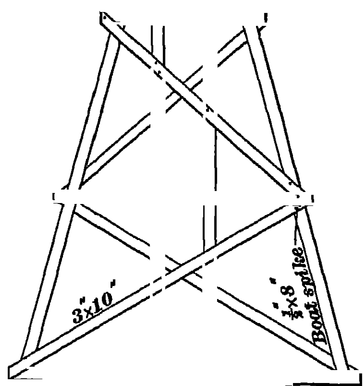


FIG 57

other, they are spiked with $\frac{1}{2}'' \times 8''$ boat spikes. Bolt fastenings may be easily removed without damaging the braces, which may be used a second time, if not decayed. Spikes, on the other hand, are difficult to draw, and sway-braces are often split or broken in removing them from the bents However, second-hand trestle material is of little value, and, as spikes are a sure fastening and are cheaper and more expeditious than bolts, they are to be recommended

When the piles of a bent are out of line, so that the sway-brace cannot lie flat, they should be hewn so that the sway-brace will come in direct contact with every pile or post, or else a packing piece of the necessary thickness should be placed under the sway-brace to give it a full bearing on the bent.

35. Counter-Posts.—Framed bents exceeding a height of 30 feet are frequently stiffened by counter-posts as shown by $a\,b$ and $c\,d$, Fig. 70. Counter-posts require the dividing up of the bent into two or more stories by means of an intermediate sill $e\,f$, and are generally employed in high work, where two and sometimes three sets of counters are used.

36. Longitudinal Bracing.—Longitudinal bracing is employed in various ways. Some constructors brace every bay or span; others, every third or fourth bay. In some trestles, the bracing is placed diagonally; in others, horizontally; while in some both forms are used. Fig. 69 shows the laced form of longitudinal bracing as employed by the Pennsylvania Railroad. The caps and sills are chamfered, and the braces cut to fit them, as shown in the detail at A. The braces are fastened to both cap and sill by heavy cut spikes.

37. Lateral Bracing.—Lateral bracing, shown at $a\,b$, Fig. 71, adds much to the stiffness of a structure. These braces are usually of $6'' \times 6''$ timber, bolted together at their intersection c with either $\frac{5}{8}$-inch or $\frac{3}{4}$-inch bolts. They are slightly notched into the caps, to which they are fastened, with heavy cut spikes. They contribute much toward keeping the track in line, and serve to a considerable extent the purpose of longitudinal bracing. Whatever the style of

bracing employed, it must be borne in mind that the effectiveness of bracing depends largely on the thoroughness with which it is fastened to the parts to be strengthened. Sway-bracing is usually fastened to the cap and sill with $\frac{3}{4}$-inch bolts, and spiked to the posts or piles with boat spikes. Diagonal braces, especially those framed or notched into the bent timber, are frequently found loose and ineffective. When spiked or bolted to place, they should fit snugly and be at least slightly strained.

38. Trestles on Curves.—Wherever possible, curved trestles should be avoided. The additional stress due to the centrifugal force of heavy trains at high speed is a severe tax on the structure, and the locating engineer should, if possible, so modify his line as to place all trestles on tangents. Circumstances, however, sometimes render the curved trestle a necessity, in which case the outer posts must have an increased batter and the outer rail its proper elevation.

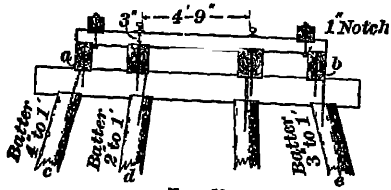


FIG 58

There are various methods of elevating track on curved trestles, three of which are shown in Figs. 58, 59, and 60. In Fig. 58, the elevation is effected by cutting off the piles or framing the posts to such lengths as will afford the requisite elevation. This is the simplest and easiest method of elevating the outer rail of a trestle. There are no shims to get out of place or that will need renewing, and there is no increase in cost above that of a trestle on a straight line.

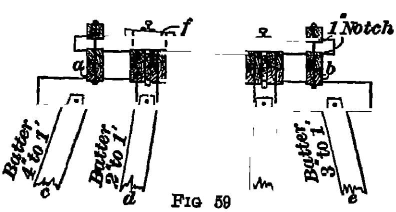


FIG 59

In Fig. 59, the outer rail is elevated by means of a shim *f*, which is placed under the rail and fastened to the tie with cut spikes. The weak point in this mode of elevating the outer rail, aside from the cost of making and fastening the

shims, is the accumulation of moisture under the shims, which induces their decay and the decay of the ties also.

In Fig. 60, the elevation is effected by cutting away a portion of the cap at *a* to an amount equal to the required elevation. The stringers are then placed in a horizontal position, as shown in the figure, and the notches in the ties beveled so as to fit the top of the stringers.

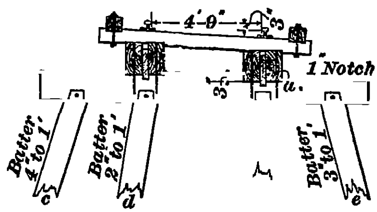


FIG 60

In pile bents, the caps are usually drift-bolted to the piles; in framed bents, the connection is usually made with mortise and tenon. In all three methods, the stringers are drift-bolted to the caps. In Figs. 58 and 59, the jack-stringers *a* and *b* add considerably to the stability of the structure, and are an additional safeguard in case of derailment. Both posts or piles *c*, *d* on the outside of the curve are battered, the outside one at a batter of 4 inches to the foot, and the next inside, at 2 inches to the foot. On the inside of the curve, only the outside posts or piles *e* of the bent are battered, at the usual batter of 3 inches to the foot. If the trestle is a high one, it should be strengthened by additional bracing.

DETAILS AND SPECIFICATIONS

DETAILS

SPIKES, BOLTS, ETC.

39. Spikes.—There are two kinds of spikes used in trestle building; namely, **cut spikes**, Fig 61, which are formed like ordinary cut nails and manufactured in the same way; and **boat spikes**, Fig. 62, which are forged from bars of wrought iron. Spikes of the same length are not necessarily of the same weight. Slender spikes are not suited for trestle building, as they are likely to bend and break, and are besides lacking in holding power. Those having good-sized heads and bodies should always be used. Steel spikes are to be preferred to iron ones, as they are tougher and stronger. Boat spikes, shown in Fig 62, have strong, well-formed heads, and are *chisel-pointed*. They are used to fasten guard-rails to ties, ties to stringers, and sway-bracing to bents.

Fig 61

Fig 62

40. Drift Bolts.—Drift bolts commonly resemble boat spikes in shape, but are much larger, and their heads are less carefully shaped. Very often the bolts are used without either head or point, being simply sheared from rods to a proper length, and driven into the holes bored to receive them The ordinary shapes are shown in Fig. 63. For fastening 12-inch caps to posts or piles, drift bolts of ¾-inch square or ¾-inch round iron, and 20 inches long, are commonly used. They should always penetrate the last timber into which they are driven far enough to resist any usual pull or shock that may

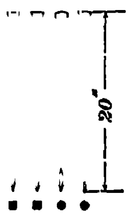


Fig. 63

be placed on them. Holes are always bored to receive drift bolts; they should be of such size that, in driving, the fibers of the wood will fill all space not occupied by the bolt itself.

41. Dowels.—In place of drift bolts, short iron rods, either square or round, called **dowels**, are frequently used. They have neither point nor head, but are sheared from rods, care only being taken to make them straight. They are frequently used to fasten caps to posts, posts to sills, and ties to stringers A common size of dowel for fastening caps to posts and posts to sills is $\frac{3}{4}$ inch round or square by 8 inches long, and weighing about 1 pound each.

Dowels of $\frac{5}{8}$-inch round iron, 5 inches in length, are well suited for fastening ties to stringers.

42. Bolts.—Bolts for holding the stringer pieces together and fastening the braces, guard-rails, etc. are commonly of $\frac{3}{4}$-inch round iron, their lengths, of course, depending on the purpose for which they are to be used The bolt heads should be well formed and of good weight, and the threads right-handed and well cut. Square nuts with a thickness equal to the diameter of the bolt and a length of side equal to twice the diameter of the bolt are the best. The outer top corners of both head and nut should be chamfered.

A cast-iron washer from 3 to $3\frac{1}{2}$ inches in diameter should be placed under the head and nut of all bolts. To insure a close fit, holes of $\frac{1}{16}$ inch less diameter than the bolts are bored through the timber to receive them.

In ordering bolts, the term *grip*, as sometimes employed, signifies the total thickness of the material to be held together—in other words, the distance between the inside faces of washers.

43. Lagscrews.—A **lagscrew**, Fig. 64, is a large screw used instead of a bolt. The head is shaped like a bolt head, and an ordinary wrench may be used in putting the screw in place. A hole of the full size of the shank of the screw is bored through the first timber, and a much smaller one is bored for the rest of the distance through which the thread is to pass. A

FIG 64

wrought or punched washer cut from sheet iron should be placed under the head of each lagscrew.

44. Washers.—Cast washers are largely used in trestle building. One should be placed under the head and nut of every bolt used in the structure. The more common forms of cast washers are shown in Fig. 65. The solid washers are placed under the head, and the slotted washers, or those having a second hole, under the nut. The purpose of the

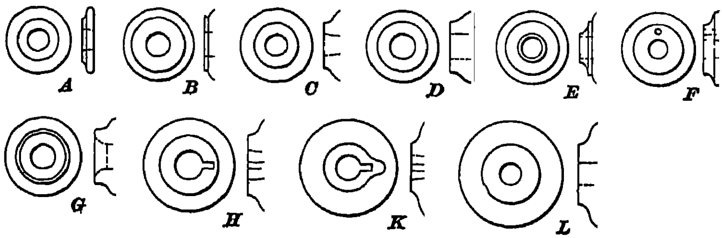


FIG 65

slot, or second hole, is to provide for locking the nut. After the nut is well tightened, a nail is driven in the slot or hole, with the head projecting far enough above the face of the washer to permit of its being drawn with a claw hammer. This effectually locks the nut. Wrought nuts may be effectually locked by nicking the thread with a center punch after the nut has been screwed home.

CONNECTION WITH EMBANKMENT

45. Abutments for Trestles.—The profile of the natural surface immediately under a trestle has, at the ends of the trestle, banks that are comparatively steep. The trestle is generally designed so that the first trestle bent will have a considerable height (10 feet or more), and then there will be a single span of perhaps 15 feet between that trestle bent and the abutment. In some of the best work, the abutment is a masonry wall such as might serve for the abutment of a smaller bridge; in other cases, a crib having a somewhat different form from the crib described in Art. 18

is used; and in other cases, a bank bent is employed, as will be explained presently.

46. Crib Connection.—The crib is usually built of 12″ × 12″ timbers halved one into the other and drift-bolted at each intersection of the timbers. There are several

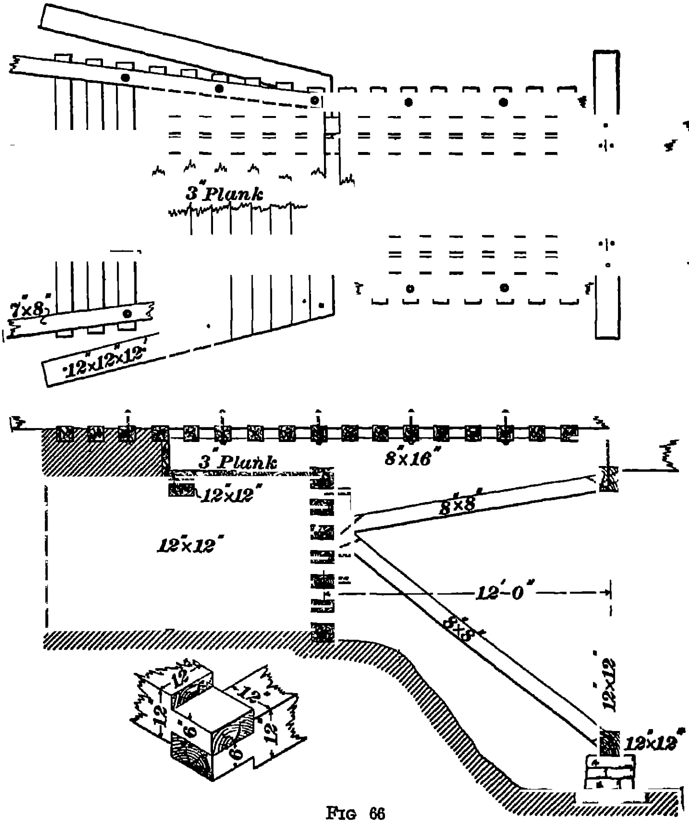


Fig 66

courses of timbers, according to the height of the embankment. The building of the crib should be deferred until the rest of the trestle is completed, so as to allow time for the settlement of the embankment. Before commencing the crib, a space of ample size to receive it should be excavated from the end of the embankment, and the earth should be

well rammed for a foundation before the timbers are put in place The proper elevation for this foundation should be determined by the engineers, so that the top of the crib may have the proper elevation without making it necessary to hew away any of the timber. The timbers composing the front of the crib—that is, the part facing the trestle—should be at least 10 feet long, and those parallel to the track, of equal length. The top of the crib should be fixed exactly at grade, so that trains may pass from the embankment to the trestle, and vice versa, without any jolting. Timbers frequently vary $\frac{1}{2}$ inch in thickness, so that the actual elevation of the top of the crib may vary 1 inch or 2 inches from the calculated elevation. This discrepancy may be easily remedied by shims, if the top of the crib is too low, and by notching down the stringer, if the top is too high It is well to have the stringers extend back from the face of the crib several feet. The bottoms of the stringers should be kept from coming in contact with the earth of the embankment. This may be accomplished by spiking planks to the crib timbers underneath the stringers. The stringers should be drift-bolted to the crib timbers. The skeleton construction for the cribwork and a filling of broken stone, as described in general in Art 18, would be preferable to the method illustrated in Fig. 66, since there would be less liability to decay.

47. Bank-Bent Connection.—Connection between the embankment and the trestle may be made by means of a **bank bent,** either of piles or framed. This construction, which is illustrated in Fig. 67, is more favored than the crib form previously described. It consists of a strong frame or pile bent built into the slope at the end of the embankment for the support of the stringers. If piles are used, the bent should contain four piles deeply driven into the embankment, so that they will not only safely carry the train load, but will sustain the pressure of the back filling, which is carried up to the base of the stringers To hold this filling in place, the back of the bent is close planked with 3-inch or 4-inch plank When the bank bent is of considerable height, struts

of 8″ × 8″ timber should extend from the bank bent to the timbers of the first trestle bent, to insure its stability. When the bank bent is of framed timber, special pains

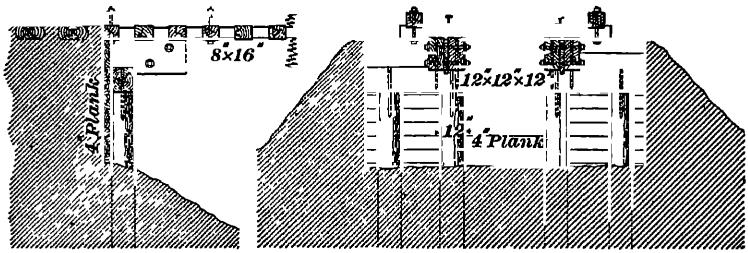


FIG 67

should be taken to insure a safe foundation for the sill. Sub-sills of 12″ × 12″ timber, laid in trenches, form a good foundation. Before laying the sub-sills, the ground should be thoroughly rammed to prevent settlement.

REFUGE BAYS, FOOTWALKS, AND FIRE-PROTECTION

48. Refuge Bays.—On all trestles of a length of 200 feet or more, **refuge bays** should be built where workmen or trackwalkers can find safety when overtaken by a train. They consist of small projecting platforms supported by ties having the necessary additional length. A refuge bay of approved pattern is shown in Fig. 68. On trestles of a length exceeding 1,000 feet, every fourth refuge bay should be large enough to contain a hand car and section gang. While repairs are being made on a trestle, before work is commenced, the hand car, together with all idle tools, should be placed in a refuge bay, and should remain there until the work is finished.

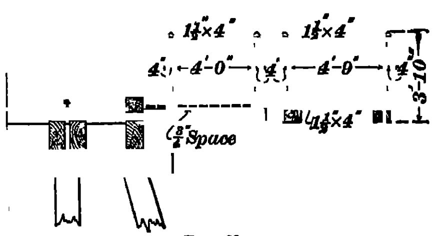


FIG 68

49. Footwalks.—On some roads, it is customary to place between the rails a footwalk of 1-inch boards from 1 to 2 feet in width. This is a bad plan, for it encourages the public to use a trestle as a thoroughfare on account of the ease in crossing it; it increases the danger of fire, as the walk forms a lodgment for coals dropped from the fireboxes of the engines, and it tends to careless inspection on account of the difficulty of reaching the parts of the structure that are covered by the walk.

50. Fire-Protection.—Every trestle should be provided with the means of protection against fire. This is sometimes effected by covering the tops of ties and stringers with sheet iron. Another method of protection is afforded by water stored in tubs at intervals of not more than 200 feet, and provided either with buckets or large dippers. The buckets should be of metal, wood pulp, or paper; metal well painted is preferable. The trackwalker should examine all tubs at least once each week and report their condition to the section foreman, whose business it is to keep them full of water. Kerosene barrels sawed in two make excellent tubs, being cheap and enduring.

An equally important safeguard against fire is the cutting and burning of all grass and brush from the right of way adjacent to the trestle, and the removal and burning of all rubbish that could afford any lodgment for sparks. The grass and brush should be cut early in the season, when the stubble is too green to burn.

It is the contractor's business to protect the trestle against fire during construction by the removal and burning of all brush and rubbish that can in any way threaten its safety. A clause to this effect should have a place in every contract.

FIELD WORK

51. Locating Bents.—The number of bents composing the trestle and the number of the station at the beginning and at the end of the trestle are determined from an inspection of the profile. The center line of the trestle is then run

in, a plug being driven on the center line locating each bent. It is customary to place these center plugs 1 foot in advance of the bent centers, so that they will not be disturbed while the bents are being placed in position. The center plugs having been driven, the transit is set up at each plug and stakes are set at right angles to the center line, giving the direction of the sill. These stakes are, like the center plug, 1 foot in advance of the required center line of the sill. In case the trestle is built on a curve, the bents should stand on radial lines.

It is of the first importance that the levels be correct, and to facilitate the checking of them, a bench mark should be established at the end of the trestle, and another near the lowest point of the line over which the trestle passes. At the center plug, a strong stake should be driven, having its top level with the top of the foundation for that bent. One grade stake at each bent is sufficient, as the workmen can transfer that elevation to other points, if necessary, with an ordinary carpenter's or mason's level.

52. Erecting.—Trestle bents of moderate height are framed lying flat on the ground, with the sills so placed that when the bent is raised it will occupy its proper position. The raising is effected by means of blocks and a fall, the power being ordinarily applied by either horses or a gang of men The end bent is first raised and braced in position, and the tackle for raising the next bent attached to it. Before a bent is raised, stay-ropes should be attached to it to give it steadiness and prevent it from being pulled over after reaching an upright position. As soon as a bent is raised, it should at once be fastened in position by means of **stay-lath** nailed to it and the bent immediately preceding. The sway-bracing should be fastened immediately, and when no longitudinal bracing is to be added, the stringers should be put in place and fastened before another bent is raised.

High trestles, composed of several sections placed one above the other, and separated by purlins (see Fig 72), are usually erected as follows: The bottom deck having been

raised, the purlins are arranged on it, and a temporary floor is laid on the purlins, on which the bent forming the next section is placed and raised precisely as though it lay on the ground.

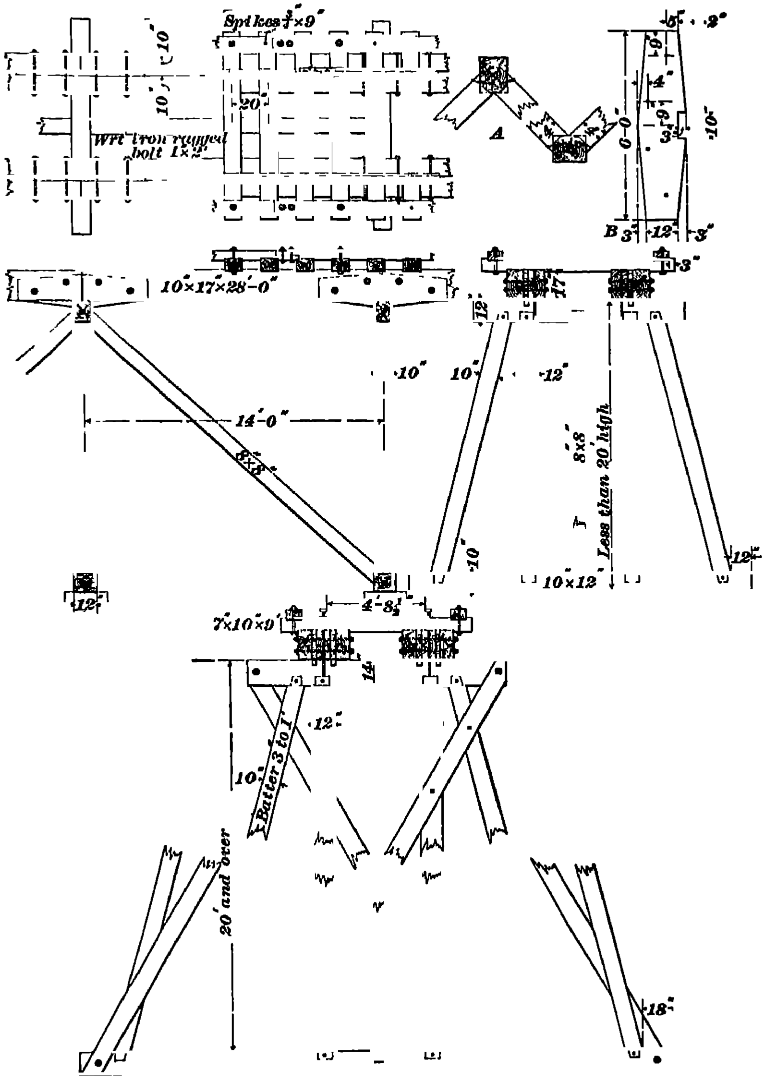
Special designs require special methods, but the plan generally adopted is the one just given. A tack or nail is driven in each cap on the center line for the accurate placing of the stringers. After the ties and guard-rails are in place and fastened, tacks are driven in ties at intervals of about 50 feet, to guide the tracklayers.

53. Preservation of Joints.—At every point where two pieces of timber come in contact, they should be painted with some preservative material. As trestle timbers are usually rough, a considerable quantity of material is necessary, if all joints are to be properly treated. White lead, though effective, is too expensive. Hot coal tar is a cheap and effective wood antiseptic, and available everywhere. Creosote oil is also much used, and when the finances of the company permit it, a trestle built of timber that has been thoroughly treated with creosote oil under pressure is undoubted economy.

STANDARD AND HIGH TRESTLES

54. Standard Plans for Trestles.—In Figs. 69, 70, and 71 are shown, in complete detail, several standard plans for trestles. These details should be studied closely as examples of details that have been previously described.

55. High Trestles.—Very high trestles call for the best engineering skill and a special design Recent practice has modified considerably many details that are so common in ordinary trestles. More iron is introduced and less framing. Posts and sills are fastened together with dowels instead of with mortise and tenon, braces are fastened with bolts, and, wherever possible, the cutting of timber incident to framing is avoided. The braces are increased in size and reduced in number. Instead of short braces framed into the posts at each angle, long braces,

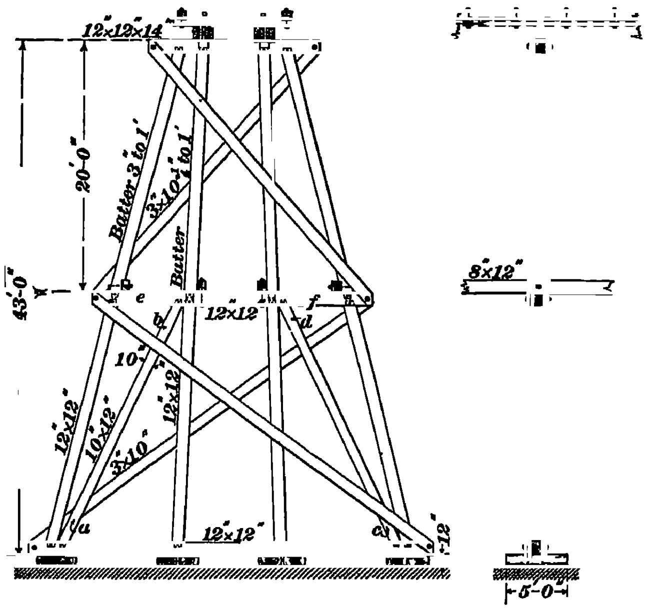


STANDARD FRAMED TRESTLE, PENNSYLVANIA RAILROAD

FIG. 69

reaching from one-half to the total width of the bent, are bolted to the main timbers. By this means, the strains due either to the wind pressure or the train load are distributed throughout the structure.

The trestle shown in Fig. 72 is a copy of one built on the line of the Oregon & Washington Railroad. Its height from ground to rail is about 100 feet. A trestle of this design is very simple and strong. By battering the inside posts,

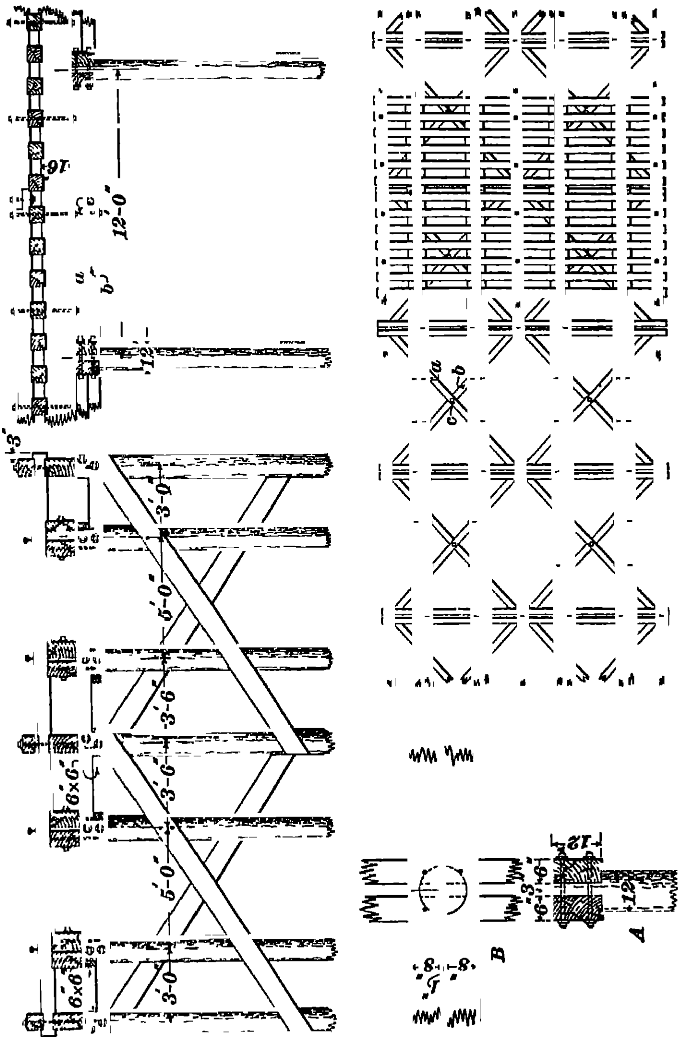


STANDARD FRAMED TRESTLE, OHIO CONNECTING RAILWAY

FIG. 70

the load is well distributed over the base, which has sufficient breadth to insure stability. The system of sway-bracing is exceptionally good. The horizontal wales *a*, *b*, and *c*, which are bolted to the posts, practically double the number of decks and reduce the post lengths to one-half their actual length. They also form seats for the purlins *d*, *f*, and *h*.

Each bent consists of three sections of equal height, separated by eight 12″ × 12″ purlins *e*, *g*. These purlins extend



STANDARD DOUBLE-TRACK PILE TRESTLE, BOSTON & ALBANY RAILROAD

FIG 71

longitudinally the length of two bents, breaking joints like stringers, and form decks on which the successive sections rest. The purlins are notched down 1 inch on the caps, and

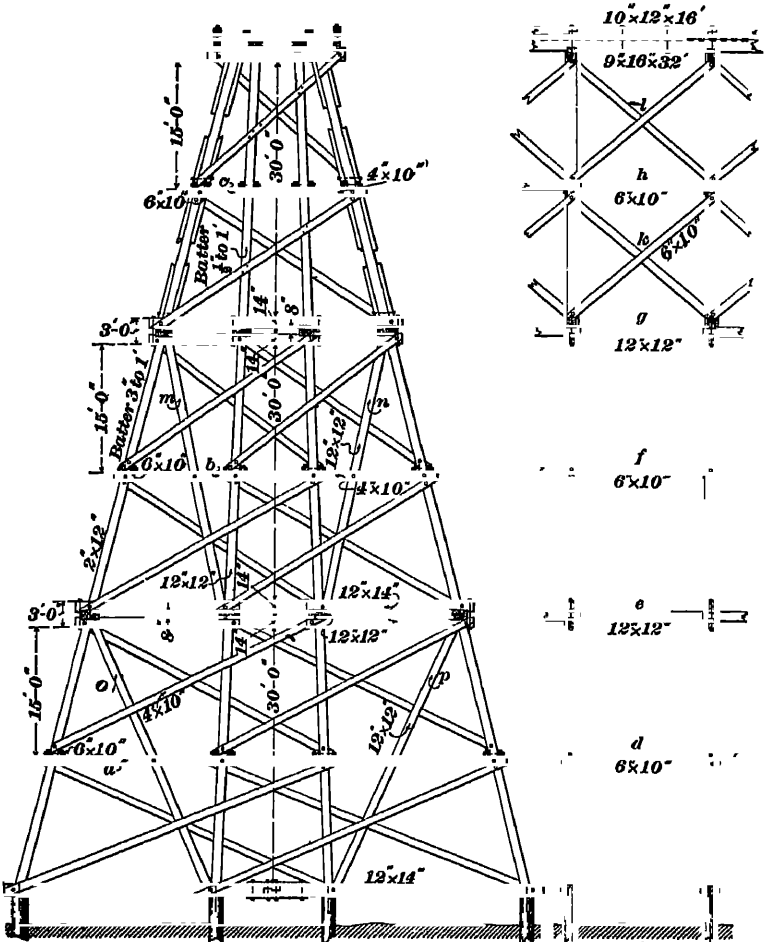


FIG 72

are also notched 1 inch to receive the sills of the bent resting on them. The caps and sills of succeeding sections are bolted together. The purlins constitute the entire longitudinal

bracing, except in the upper section, where diagonal braces *k*, *l* are employed. It would add considerably to the stability of the structure if similar braces were placed in every panel from the ground upwards The plan shows but one dowel at each connection of post with sill. Two would be a better number, especially in the case of the outside batter posts and the counter-posts *m*, *n*, *o*, and *p*.

TRESTLE DESIGN

56. Trestles can be designed by the same general principles that are used in the design of bridges and roof trusses. Nearly all railroads, however, have standard sizes of timber that they use for the construction of all trestles, regardless of any special conditions. Thus, $12'' \times 12''$ timber is commonly adopted as a standard size for posts, caps, and sills. The adoption of these uniform sizes, which experience has shown to be more than ample, is defended on the ground that the construction department can do their work best by employing uniform sizes of trestle stuff. When any trestle is needed, especially a temporary trestle that must be constructed with great rapidity after a bridge has been wrecked, several car loads of trestle stuff of all lengths and sizes can be rushed to the spot, and the trestle put up in a short time Under such special circumstances, the employment of uniform sizes has its undoubted advantages; and, under all circumstances, it saves the work and expense of designing every trestle by itself. Where timber is scarce or expensive, however, it may sometimes prove economical to make a careful calculation of the sizes that are actually necessary. And even where standard sizes are used, they should not be adopted arbitrarily, but should be so chosen or designed that the structure will be safe under the most unfavorable conditions.

SPECIFICATIONS FOR WOODEN TRESTLES

57. The following specifications are general, but are sufficiently detailed to guide in making an application to any particular structure. Special conditions may make it necessary to omit or change some of the items or to insert new ones.

58. Clearing.—Before beginning work on any structure, the ground must be entirely cleared of logs, stumps, trees, and brush of every description All combustible material must be piled at convenient places and completely burned Trees outside the right of way that, by falling, may endanger the trestle, must be felled by the contractor, it being understood that permission to fell such trees shall be obtained by the railroad company from the landowner Such portions of the right of way as shall be deemed necessary by the engineer shall be grubbed.

59. Drawings.—The drawings are to the scale indicated and marked, but in all cases the figures are to be taken, and, in case of omission, the engineer in charge is to be referred to for dimensions Under no circumstances are the drawings to be scaled either by the contractor or by any of his men The engineer will be required to mark the dimensions on the contractor's blueprint and keep a record of the same in his office

60. Dimensions.—All posts, braces, clamps, stringers, packing-blocks, ties, guard timbers, sills, and all timber generally shall be of the exact dimensions given and figured on the plan Variations from these will be allowed only on the written consent of the engineer in charge

61. Timber.—All timber shall be of good quality and of such kinds as the engineer shall direct, and be free from wind shakes, black, loose, or unsound knots, worm holes, and all signs of decay It must be sawed true, and out of wind, and full size Under no circumstances shall any timber cut from dead logs be allowed to be placed in any part of the structure; all timber must be cut from living trees.

62. Piles.—Piles shall be cut from live, thrifty timber They will be either round or square, as may be required by the engineer. Round piles must be straight, be stripped of all bark, and be well trimmed They must be at least 12 inches in diameter at the cut-off when cut to grade to receive the cap. The smaller end must be at least 8 inches in diameter.

Square piles must be hewn (or sawed) 12 inches square. They must have at least 9 inches of heart wood on each face from the head of the pile after being cut off to grade, to 5 feet below the surface of the ground into which the pile is driven.

All piles must be properly pointed They shall, if required, be shod with shoes of cast or wrought iron, made according to plans furnished by the engineer. In driving, they shall be banded with wrought-iron rings of suitable weight to prevent splitting The actual cost, delivered on the ground, of the necessary shoes and rings will be allowed to the contractor Piles must be driven to hard bottom or until they do not sink more than 5 inches under the last five blows from a hammer of at least 2,000 pounds weight falling free 25 feet. All piles damaged in driving, or driven out of place, shall be either withdrawn or cut off, as the engineer may direct, and others driven in their stead The piles thus replaced will not be paid for. All piles under track stringers must be accurately spaced and driven vertically, and in each bent the batter piles must be driven at the angle shown.

Piles shall be measured by the lineal foot after they are driven and cut off, and the price per lineal foot shall be understood to cover the cost of transportation, removing the bark, driving, cutting off, and all labor and materials required in the performance of the work, but that portion of each pile cut off shall be estimated and paid for by the lineal foot as "piles cut off "

The contractor must give all facilities in his power to aid the pile recorder in his duties.

Parts of pile heads projecting beyond the cap must be adzed off at an angle of 45°.

63. Framing.—All framing must be done to a close fit and in a thorough and workmanlike manner. No blocking or shimming of any kind will be allowed in making joints, nor will open joints be accepted

All joints, ends of posts, piles, etc , and all surfaces of wood on wood shall be thoroughly painted with hot creosote oil and covered with a coat of thick asphaltum, hot asphaltum, or hot common tar; or they shall be given a good thick coat of white lead ground and mixed with pure linseed oil

All bolt and other holes bored in any part of the work must be thoroughly saturated with hot creosote oil, hot asphaltum, hot tar, coal tar, white lead mixed with pure linseed oil, or linseed oil

All bolts and drift bolts before being put in place must be warmed and coated with hot creosote oil, hot asphaltum, hot tar, or hot coal tar, or they shall be coated with white lead and linseed oil.

All bolt holes for bolts ¾ inch in diameter or over must be bored with an auger ⅛ inch smaller in diameter than the bolt, in order to

secure a perfectly tight fit of the bolt in the hole. For bolts $\frac{5}{8}$ inch in diameter or smaller, the auger must be $\frac{1}{16}$ inch smaller

64. Trestles on Curves.—Trestles built on curves must have the outer rail elevated according to plans furnished from the chief engineer's office, a copy of which will be delivered to the contractor

65. Creosoted Trestles.—All piles used in creosoted trestles must be completely stripped of bark, and be pointed before treatment None of the sap wood may be hewn from the piles No notching or cutting of the piles will be allowed after treatment, except the sawing off of the head of the pile to the proper level for the reception of the cap, and the beveling of such part of the head as shall project from under the cap

The heads of all creosoted piles, after the necessary cutting and trimming has been done for the reception of the cap, must be saturated with hot creosote oil, and then covered with hot asphaltum before the cap is put in place

Timber for creosoted trestles must be cut and framed to the proper dimensions before treatment No cutting or trimming of any kind will be allowed after treatment, except the boring of the necessary bolt holes

Hot creosote oil must be poured into the bolt holes before the insertion of the bolts, in such a manner that the entire surface of the holes shall receive a coating of the oil.

66. Treatment of Creosoted Piles and Timber.—All creosoted timber and piles shall be prepared in accordance with the following process The timber and piles, after having been cut and trimmed to the proper size and shape, shall be submitted to a contact steaming inside the injection cylinders, which shall last from 2 to 3 hours, according to the size of the timber, then, to a heat not to exceed 230° F , in a vacuum of 24 inches of mercury, for a period long enough to dry the wood thoroughly The creosote oil, heated to a temperature of about 175°, shall then be let into the injection cylinder and forced into the wood under a pressure of 150 pounds per square inch, until not less than 15 pounds of oil to the cubic foot has been absorbed. The oil must contain at least 10 per cent of carbolic and cresylic acids, and have at least 12 per cent of naphthalene.

67. Iron.—(*a*) *Wrought Iron* —All wrought iron must be of the best quality of American refined iron, tough, ductile, and uniform in quality, and must have an elastic limit of not less than 26,000 pounds per square inch

All bolts must be perfect in every respect, and have nuts and threads of the full standard size corresponding to their diameters The thickness of the nut shall not be less than the diameter of the bolt, and the side of its square not less than twice the diameter of the bolt

The heads of all bolts shall be square, round button, or countersunk (1) When square, the thickness shall not be less than the diameter of the bolt, and the side of its square not less than twice the diameter of the bolt (2) When round button, the thickness at center shall not be less than three-quarters of the diameter of the bolt, and the extreme diameter not less than two and one-half times the diameter of the bolt (3) When countersunk, the extreme diameter of head shall not be less than twice the diameter of the bolt, and it shall be countersunk on the under side so as to fit into a cup washer.

(*b*) *Cast Iron* —All castings must be of good tough metal, of a quality capable of bearing a weight of 550 pounds, suspended at the center of a bar 1 inch square, and 4½ feet between supports. They must be smooth, well-shaped, free from air holes, cracks, cinders, and other imperfections.

All iron must be thoroughly soaked in boiled linseed oil before leaving the shop.

68. Inspection and Acceptance.—All materials must be subject to the inspection and acceptance of the engineer before being used The contractor must give all proper facilities for making such inspection thorough

Any omission by the engineer to disapprove the work at the time of a monthly or any other estimate being made shall not be construed as an acceptance of any defective work

69. Protection Against Fire.—The contractor must, each evening before quitting work, remove all shavings, borings, and scraps of wood from the deck of the trestle and from proximity to the bents, and on the completion of the work must take down and remove to a safe distance all staging used in the erection of the work, and remove and burn all fragments of timber, shavings, etc

70. Roads and Highways.—Commodious passing places for all public and private roads shall be maintained in good condition by the contractor, and he shall open and maintain thereafter a good and safe road for passage on horseback along the whole length of his work.

71. Running of Trains.—The contractor shall so conduct all his operations as not to impede the running of trains or the operation of the road. He will be responsible to the railroad company for all damages to rolling stock or damages from wrecks caused by his negligence The cost of such damage will be retained from his monthly and final estimates.

72. Risks.—The contractor shall assume all risks from floods, storms, and casualties of every description, except accidents caused by the railroad company, until the final estimate of the work

73. Labor and Material.—The contractor must furnish all labor and material incidental to or in any way connected with the manufacture, transportation, erection, and maintenance of the structure until its final acceptance

Disorderly, quarrelsome, or incompetent men in the employ of the contractor, or those who persist in doing bad work in disregard of these specifications, must be discharged by the contractor when requested to do so by the engineer

Whenever the chief engineer may deem it advisable, he may name the rates and prices to be paid by the contractors, for such time as he may designate, to the several classes of laborers and mechanics in their employ, and for the hire of horses, mules, teams, etc , and these shall not be exceeded; and having given due notice to the contractors of his action in regard to these matters, the contractors shall be bound to obey his orders in relation thereto The chief engineer shall not, however, name a rate or price for any class of labor, etc higher than the maximum rates being paid by the contractor paying the highest for that class.

74. Damages and Trespass.—Contractors shall be liable for all damages to landholders, arising from loss of or injury to crops or cattle, sustained by any cause connected with the works or through any of the contractors' agents or workmen Contractors shall not allow any person in their employ to trespass on the premises of persons in the vicinity of the works, and shall, at the request of the engineer, discharge from their employ any person that may be guilty of committing damage in this respect They shall also maintain any fences that may be necessary for the protection of any property or crops

75. Removal of Defective Work.—The contractor must remove at his own expense any material disapproved by the engineer, and must remove and rebuild, without extra charge and within such time as may be fixed by the engineer, any work appearing to the engineer, during the progress of the work or after the completion, to be unsound or improperly executed, notwithstanding that any certificate may have been issued as due for the execution of the same The engineer shall, however, give notice of defective work to the contractor as soon as he shall have become cognizant of the same On default of the contractor to replace the work as directed by the engineer, such work may be done by the railroad company at the contractor's expense

76. Delays.—No charge shall be made by the contractor for hindrances and delay, from any cause, in the progress of the work, but it may entitle him to an extension of the time allowed for completing

the work, sufficient to compensate for the detention, to be determined by the engineer, provided he shall give the engineer in charge immediate notice, in writing, of the detention

77. Extra Work.—No claim shall be allowed for extra work, unless done in pursuance of a written order from the engineer, and unless the claim is made at the first estimate after the work is executed. The chief engineer may, at his discretion, allow any claim, or such part of it as he may deem just and equitable.

Unless a price is specified in the contract for the class of work performed, extra work will be paid for at the actual cost of the material remaining in the structure after its completion and the cost of the labor for executing the work, plus 15 per cent. of the total cost. This 15 per cent will be understood to include the use and cost of all tools and temporary structures, staging, etc , and the contractor's profit, and no extra allowance over and above this will be made.

78. Information and Force Accounts.—The contractor shall aid the engineer in every way possible in obtaining information, and freely furnish any which he may possess, by access to his books and accounts, in regard to the cost of work, labor, time, material, force account, and such other items as the engineer may require for the proper execution of his work, and shall make such reports to him from time to time as the engineer may deem necessary and expedient

79. Prosecution of the Work.—The contractor shall commence his work at such points as the engineer may direct, and shall conform to the engineer's directions as to the order of time in which the different parts of the work shall be done, as well as the force required to complete the work at the time specified in the contract In case the contractor shall refuse or neglect to obey the orders of the engineer in the above respects, the engineer shall have the power to either declare the contract null and void and relet the work, or to hire such force and buy such tools at the contractor's expense as may be necessary for the proper conduct of the work, as may in his judgment be for the best interests of the railroad company

80. Changes.—At any time during the execution or before the commencement of the work, the engineer shall be at liberty to make such changes as he may deem necessary, whether the quantities are increased or diminished by such changes, and the contractor shall not be entitled to any claim on account of such changes beyond the actual amount of work done according to these specifications at the prices stipulated in the contract, unless such work is made more expensive to him, when such rates as may be deemed just and equitable by the chief engineer will be allowed him, if, on the other hand, the work is made less expensive, a corresponding deduction may be made.

81. Quantities.—It is distinctly understood that the quantities of work estimated are approximate, and the railroad company reserves the right of building only such kinds and quantities, and according to such plans, as the nature or economy of the work may in the opinion of the engineer, require

82. Engineer.—The term **engineer** will be understood to mean the chief engineer, or any of his authorized assistants or inspectors, and all directions given by them, under his authority, shall be fully carried out by the contractor and his agents and employes

83. Price and Payment.—The prices bid will include the furnishing of materials, tools, scaffolding, watching, and all other items of expense in any way connected with the execution and maintenance of the work until it is finally accepted and received as com pleted The contractor shall be paid only for the piles, timber, and iron left in the structure after completion No wastage in any kind of material will be paid for except in the case of piles, when the "piles cut-off," which cannot be used on any other part of the contractor's work, will be paid for at the rate agreed on After the material cut off is paid for, it is to be considered the property of the railroad company, and is to be neither removed nor used by the contractor without the consent of the engineer, and then only on the repayment of the price which has been paid for it

The piles and "piles cut-off" will be paid for by the lineal foot, the former driven in place

The timber and lumber remaining in and necessary to the completed structure will be paid for by the thousand feet, board measure.

The iron remaining in the structure after its completion will be paid for by the pound

The masonry for foundations will be paid for by the cubic yard

The excavations for foundations will be paid for by the cubic yard.

The retained percentage will not be paid on the cost of any single structure until the *final estimate* is due on the entire work embraced in the contract.

TRACKWORK
(PART 1)

TRACK MATERIALS AND CONSTRUCTION

TRACK MATERIALS

BALLAST

1. Introduction.—The continuous finished surface of the cuts and embankments, or fills, on a line of railway is known as the *subgrade*, or *roadbed* In cuts a ditch is formed on each side to drain the subgrade and carry off rainwater For single-track lines the width ranges from 16 to 22 feet over the edges of fills and between the ditches in cuts. For double track with tracks 13 feet between centers, the width is 30 to 35 feet In some cases the roadbed is flat, but in general the center is made 3 to 8 inches higher than the edges in order to give a slope for drainage On the subgrade is laid the track, which consists of a bed of ballast supporting cross-ties to which are spiked the rails to carry the wheels of trains

2. Purpose of Ballast.—The soil or earth of the subgrade is not firm enough to support the ties directly, and as it does not drain readily, it is likely to be softened by rain and heaved by frost For these reasons the subgrade is covered with a layer of suitable loose material called *ballast* to provide for drainage of the track, to distribute the load of trains over the surface of the roadbed, and to enable track to be leveled or surfaced On this layer of ballast the ties are placed. For

ordinary main track a 12-inch depth of ballast under the ties is usually employed The principal materials, mentioned in the order of their value, are crushed stone, washed gravel, slag, plain gravel, burned clay, and cinders.

3. Crushed Stone.—For first-class track carrying heavy and high-speed passenger traffic, crushed-stone ballast is generally used; for, although it is the most expensive, it is practically dustless and it holds the track in place better than do most other materials A hard grade of stone is needed, preferably trap or limestone, in pieces ranging in size from $\frac{3}{4}$ inch to $2\frac{1}{2}$ inches Since dirt and engine cinders gradually collect in the ballast and prevent proper drainage, the ballast is usually taken up every few years, screened, and replaced. From 15 to 25 per cent. of new material is required when the ballast is put back.

4. Gravel.—Washed gravel is about as good for ballast as crushed stone, and screened gravel comes next. But gravel as it comes from the pit usually has so much sand and dirt in proportion to the pebbles that it will shift and settle, will not drain well, and is likely to be heaved by frost. For these reasons track with pit-gravel ballast requires more maintenance work.

5. Slag.—In iron- and steel-mill districts the slag or waste from the furnaces is largely used for ballast, but it needs to be selected carefully Good crushed slag is hard, holds the track, and drains well, but inferior qualities will disintegrate under traffic

6. Burned Clay.—The quality of burned clay depends on the quality of the clay and on thorough burning In its preparation, alternate layers of coal and clay are piled up in a long heap to a height of about 10 feet and the whole mass is then allowed to burn. This material is extensively used for ballast in the Southwest

7. Cinders.—Engine cinders from roundhouses and ashes from power houses are much used for ballast on branches and

less important lines, as well as in yards, but they are too soft and dusty for main tracks They are of special advantage for sub-ballast under more expensive material where low and wet spots are to be filled and where the track is likely to be heaved by frost.

8. Miscellaneous.—Several inferior materials are used for ballast in localities where they are plentiful and cheap These include sand, shells, chats (lead- and zinc-mill refuse), chert (a species of gravel), and culm. Earth, or so-called *mud ballast,* composed of local soil, is used only on unimportant lines. The use of such materials results in increased maintenance expenses except under light traffic.

TIES

9. Kinds of Wood.—A great number of woods are used for ties, differing widely in value and cost. Few railways can now obtain a complete supply from forests along their own lines, so that there is a wider distribution and increasing cost for transportation In Table I are listed some of the principal woods used for ties with the average periods in years that they will resist decay.

10. Life of Ties.—The life of ties in railway track depends on various factors besides the kind of wood These factors include the locality where the ties were cut, method of seasoning, climate and rainfall, drainage of ballast and road-bed, maintenance of track, weight of engines, and amount of traffic Therefore, the life of untreated ties as given in the table is only a general average

Resistance to decay and resistance to wear by the rail are equally important in determining the life of ties Thus, some soft woods having a great resistance to decay may be cut and worn out by the rail long before reaching their normal life, as given in Table I, unless they are protected by steel tie-plates Redwood ties, which will last for 12 years if thus protected, may be damaged and rendered useless in about 5 years if used without tie-plates In track carrying heavy and frequent loads

even hardwood ties may be damaged if not protected. On the other hand, white oak and black locust have high resistance to decay and wear.

The spikes that secure the rails to the ties are gradually loosened by the vibration of the rail and must be driven down from time to time. This continual movement eventually

TABLE I

LIFE OF TIES

Hardwood Variety	Years	Softwood Variety	Years
Ash	4	Cedar	6 to 8
Beech	4 to 5	Cypress	6 to 10
Birch	4 to 5	Fir, Douglas	6 to 8
Catalpa	10	Hemlock	5 to 8
Cherry	6 to 8	Larch, or Tamarack	7 to 8
Chestnut	8 to 10	Pine, Long-leaf	6 to 8
Elm	4 to 6	Pine, Western	3 to 4
Gum	3 to 4	Redwood	12
Hickory	3 to 4	Spruce	6 to 8
Locust, Black	10 to 16		
Locust, Honey	7 to 9		
Maple	4 to 5		
Oak, White	7 to 9		
Oak, Chestnut	7 to 8		
Oak, Red	3 to 4		
Poplar	5		
Sycamore	3 to 4		
Walnut, Black	8 to 10		

destroys the grip of the wood fibers, admits water, and causes rot, the tie is then said to be *spike-killed* When a spike is to be replaced, the old hole should be filled with a tight-fitting plug of wood and the spike driven into the plug. Long life of ties is economical not only in cost of ties but also in reducing expense and track disturbance due to tie renewals.

11. Seasoning.—It is important that new ties be thoroughly seasoned or dried before they are put in the track, as they will last longer and hold the spikes more securely. For this purpose they are stacked in piles of about fifty, each pile having alternate rows of two ties and seven ties, arranged as shown in Fig. 1 The seven ties are placed far enough apart to allow a free circulation of air, and the top layer is inclined so as to shed water. Ties are usually cut during the fall and winter, so that they can season while the temperature is too low to cause the sap fermentation that results in rot.

12. Kinds of Ties.—A *pole tie* is made from a tree only large enough to produce one tie; two sides are hewn or sawed and the other sides are the natural rounded surfaces. Larger

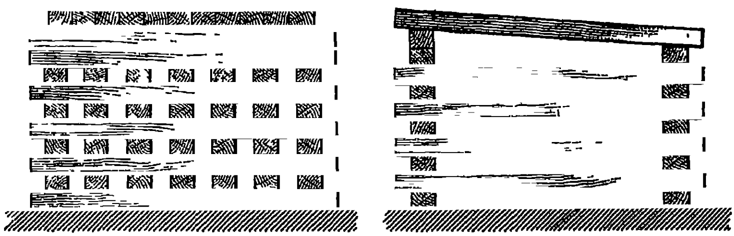


FIG 1

trees are sawed into two ties called *split ties,* or into four ties called *quartered ties.* It has been generally accepted that hewn ties are superior to those that are sawed, but it is doubtful if there is much difference, particularly if the ties are to be treated chemically The hewing takes much more time, is more wasteful, and does not give an even seat for the rail. Sawed ties are necessary on bridges and trestles where an even bearing and uniform thickness are required.

Heartwood is the harder central portion of the trunk of a tree, and sapwood is the softer outer portion next to the bark. In a heart tie the width of sapwood must be not more than one-fourth of the width of the top of the tie for a distance of from 20 to 24 inches from the middle Where there is a greater width of sapwood, the tie is called a sap tie. Ties should be laid with the heart down.

13. Size of Ties.—The length of ties is usually $8\frac{1}{2}$ feet, sometimes 8 feet, and more rarely 9 feet, the long ties being used more especially on soft or swampy ground The thickness is generally 6 or 7 inches and the width 8, 9, or 10 inches

14. Chemical Treatment of Ties.—With increasing shortage and price of first-class long-life wood ties, there is increasing use of preservative treatment with chemicals in order that softer and inferior kinds of wood may be used This is often economical, since a cheaper tie treated at small expense and protected by tie-plates may last even longer than a first-class untreated tie. Thus, a good white-oak tie costing $1.30 may have a life of 8 or 10 years, while a cheaper red-oak tie which ordinarily has a life of 3 or 4 years may last from 12 to 16 years after a treatment that brings its total cost up to $1 40 There is a tendency also to treat even the better woods, such as white oak, with chemical preservatives.

For the treatment of railway ties, creosote and zinc chloride are used principally. In both cases the seasoned ties are placed on small cars that are run into a long cylindrical chamber. Heated creosote or zinc-chloride solution is admitted to the cylinder and a pressure of from 100 to 200 pounds per square inch is applied. In one method, known as the *full-cell process,* all the liquid that can be forced in under pressure is left in the tie, but in the *empty-cell process* part of the liquid is drawn out by a vacuum, thus reducing the amount of preservative used but leaving the cell walls sufficiently well coated to prevent fermentation or fungus growth. Ties treated with zinc chloride are used mainly in dry regions, as the chemical gradually leaks out of ties in a moist climate and damp ballast. To prevent this, however, the zinc-creosote process includes a second light treatment with creosote to seal or plug the pores of the wood.

15. Substitute Ties.—The term substitute tie is applied to ties of all materials except wood Numerous experiments with substitute ties have been made in the United States, usually on a small scale. Steel ties of I-beam section with bolt fastenings are used on some eastern lines. Concrete ties in

main tracks usually have failed by cracking or crushing, but they are thought to have advantages for yards and sidings by reducing the amount of tie renewals

RAILS

16. History of Present Design.—The **T** rail or flange rail now used exclusively in the United States, and to a large extent in other countries, is developed from the design made in 1830 by Robert L. Stevens, an American engineer. As railways increased and extended, innumerable modifications were adopted by engineers of various lines, nearly every important railway having its own particular sections, many of which differed only in minor details but sufficiently to require special sets of rolls in their manufacture, thus causing trouble and expense in rail production To check this uneconomical practice, the American Society of Civil Engineers several years ago appointed a committee to study the question of rail design, and, after long investigation, a series of standards was adopted which became widely used As the heavier sections did not prove so good as was expected, the American Railway Association later adopted a modified section. Finally, the American Railway Engineering Association carried on further study and developed a set of standard sections for heavy rails, of which a typical section is shown in Fig 2 These several investigations have resulted in improved rails, with economy in manufacture and increased serivce

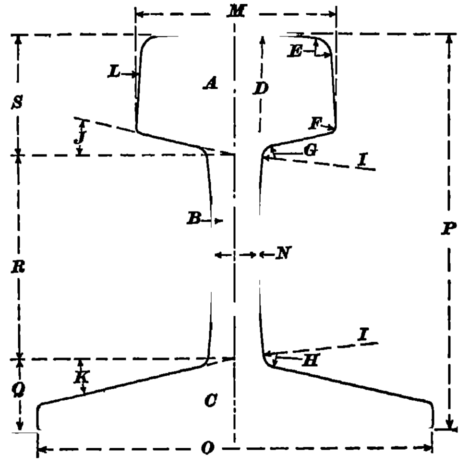


FIG 2

17. Elements of Rail Sections.—Good proportions in a rail are as essential as good metal The three parts are the head *A*, Fig 2, the web *B*, and the base, or flange, *C* The side of the head toward the center of the track is called the *gauge side* of the rail The head must be broad enough and deep enough to withstand the effects of wheels carrying heavy loads, but if it is too large in proportion to the section, the metal will not be sufficiently worked in the rolls to get the desired density and strength, while the lighter parts will also suffer. In the sections of the American Society of Civil Engineers (A S C. E sections) the proportions were uniformly 42, 21, and 37 per cent for the head, web, and base, respectively, but for the larger rails this head proportion was excessive In the American Railway Engineering Association (A R. E. A) sections these proportions range from 38 2, 22 6, and 39 2 per cent in the 90-pound rail, to 37 1, 22 7, and 40.2 per cent in the 120-pound rail.

18. Strength of Rails.—The rail must have sufficient strength to act as a beam between the ties and to give a minimum deflection under load It must also have a base width sufficient for stability In the A S C E sections the width of the base was made equal to the height to give sufficient bearing on the ties to prevent cutting the wood. Rails with very wide flanges, however, are likely to be weak in the thin edges. In the A R E A. sections the width is ample for stability, but is less than the height, reliance being placed on steel tie-plates for the protection of the tie.

Selection of the weight of rails to be used must be based upon judgment and experience, as it is impossible to determine exactly the stresses to which the rails will be subjected. This difficulty is due to the fact that the rails have not a rigid foundation, since there is an irregular settlement of the ballast and roadbed. Vertical loads due to weight are increased enormously by irregularities of track, low joints, and loose ties In addition there are severe lateral pressures, especially on curves The weight of rail, however, should have some relation to the wheel loads carried A rule of the Baldwin Locomotive

Works is that rails of less than 60 pounds per yard may carry 250 pounds for each pound per yard, the figure is 300 for rails of 60 to 90 pounds, and 350 for rails of more than 90 pounds per yard Thus a 100-pound rail may carry wheel loads up to 35,000 pounds The rule applies to good track with not less than 14 ties to each 30-foot rail length To get the weight of rail desirable for a given maximum wheel load, divide this wheel load by 250 for loads up to 15,000 pounds, use a 60-pound rail for wheel loads between 15,000 and 18,000 pounds, divide the wheel load by 300 for values between 18,000 and 27,000 pounds, use a 90-pound rail for wheel loads from 27,000 to 31,500, and for wheel loads greater than 31,500 pounds, divide by 350.

EXAMPLE —An engine has a load of 280,000 pounds on its eight driving wheels What weight of rail should be used?

SOLUTION —The load on each wheel is 280,000÷8=35,000 lb Since this is greater than 31,500, the proper weight of rail is found by dividing by 350; thus 35,000÷350=100 lb Ans

19. Weight and Length of Rails.—Rails are classified according to their weight per yard. Rails weighing less than

TABLE II

CONSTANT DIMENSIONS OF RAIL SECTIONS

Dimension	A S C E	A R E A
Top radius of head, *D*	12 in	14 in
Top corner radius, *E*	$\frac{5}{16}$ in	$\frac{1}{8}$ in
Bottom corner radius, *F*	$\frac{1}{16}$ in	$\frac{1}{16}$ in
Top fillets, *G*	$\frac{1}{4}$ in	$\frac{3}{8}$ in
Bottom fillets, *H*	$\frac{1}{4}$ in	$\frac{5}{8}$ in
Radius of web, *I*	12 in	14 in
Fishing angles, *J* and *K*	13°	1 in 4
Side of head, *L*	vertical	slope 1 in 16

75 pounds per yard are now rarely used in important main tracks The 100-pound rail is very generally adopted for lines of heavy traffic, but rails of 120 to 135 pounds per yard are in use.

TABLE III

WEIGHTS AND VARYING DIMENSIONS OF RAILS

Dimension	Weight of Rail, in Pounds per Yard								
	50	60	75	80	100	90	100	110	120
	A S C E Sections					A R. E A Sections			
Width of head, M....	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{15}{32}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{9}{16}$	$2\frac{11}{16}$	$2\frac{25}{32}$	$2\frac{7}{8}$
Web thickness, N.......	$\frac{7}{16}$	$\frac{31}{64}$	$\frac{17}{32}$	$\frac{35}{64}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{19}{32}$	$\frac{5}{8}$
Width of base, O....	$3\frac{7}{8}$	$4\frac{1}{4}$	$4\frac{13}{16}$	5	$5\frac{3}{4}$	$5\frac{1}{8}$	$5\frac{3}{8}$	$5\frac{1}{2}$	$5\frac{3}{4}$
Height, P.........	$3\frac{7}{8}$	$4\frac{1}{4}$	$4\frac{13}{16}$	5	$5\frac{3}{4}$	$5\frac{5}{8}$	6	$6\frac{1}{4}$	$6\frac{1}{2}$
Height of base, Q.....	$\frac{11}{16}$	$\frac{49}{64}$	$\frac{27}{32}$	$\frac{7}{8}$	$\frac{31}{32}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$
Height of web, R.......	$2\frac{1}{16}$	$2\frac{17}{64}$	$2\frac{35}{64}$	$2\frac{5}{8}$	$3\frac{5}{64}$	$3\frac{5}{32}$	$3\frac{9}{32}$	$3\frac{13}{32}$	$3\frac{17}{32}$
Height of head, S...	$1\frac{1}{8}$	$1\frac{7}{32}$	$1\frac{27}{64}$	$1\frac{1}{2}$	$1\frac{45}{64}$	$1\frac{15}{32}$	$1\frac{21}{32}$	$1\frac{23}{32}$	$1\frac{25}{32}$

The length of rails is usually 30 feet, but some railroads use 33 feet in order to reduce the number of joints Rails 60 feet long have been used largely in tunnels to reduce maintenance work on the joints, and at road crossings to avoid having rail joints covered by the paving On curves a certain number of rails 28 or 29½ feet long are used on the inside line so as to keep the joints approximately midway between those in the longer outside line of rails Rails worn at the ends, but otherwise good, are frequently sawed or cropped to a length of 27 feet, and then drilled for bolts like new rails.

20. Dimensions of Rails.—Although some dimensions of the different rail sections vary with the weight, others are constant. The constants for the two principal types of sections are given in Table II, in which

the letters refer to Fig 2, dimensions that vary with the weight are given in Table III

21. Chemical Composition and Tests.—Rails are made of steel produced either by the Bessemer or by the open-hearth process, the latter being now more generally used Quality in a rail in regard to strength, soundness, and resistance to wear depends largely on the chemical composition of the steel, as well as upon proper rolling In open-hearth rails of over 85 pounds per yard, the carbon may be from 62 to 75 per cent, manganese, 60 to 90 per cent, and phosphorous not more than 04 per cent In Bessemer rails the proportions would be 45 to 55 per cent of carbon, 80 to 1 10 of manganese, and not more than 10 per cent of phosphorus In both kinds of steel there would be not less than 10 per cent of silicon Alloy steels with relatively high proportions of nickel, silicon, and manganese are used to some extent.

In addition to chemical analyses of the steel, a certain number of rails from each *blow* of steel are subjected to a drop test to determine their strength A piece of rail is placed base upwards on supports 3 feet apart (or 4 feet for rails of more than 110 pounds per yard). The supports are part of an anvil block weighing 10 tons and resting on springs A hammer weighing 2,000 pounds is allowed to fall on the rail from a height varying from 16 to 20 feet, according to the weight of rail When the test piece is struck, the elongation should be within certain prescribed limits If the test piece does not break under the blow and shows the required elongation, it is nicked and broken to determine whether there are any interior defects, such as seams, cavities, or impurities If, when struck, any rail fails to show the required elongation, or if, when broken, it shows interior defects, other tests are made on rails from the same blow of steel If these fail, all the rails from that blow are rejected.

EXAMPLES FOR PRACTICE

1 The total load on the eight driving wheels of a locomotive is 230,000 pounds What weight of rails should be used? Ans 90 lb

2. A locomotive carries a load of 300,000 pounds on its eight driving wheels. Find the required weight of rails Ans 110 lb

RAIL JOINTS AND FASTENINGS

22. Rail Joints.—The ends of rails must be spliced to hold them in line both vertically and laterally, in order that the wheels will roll smoothly across the joint Further, in the suspended type of joint, which is described later, the splice has to support the overhanging ends of the rails, and it should make the joint practically as strong as the body of the rail. This latter aim is rarely realized and rail joints are nearly always an important feature in track maintenance work As a rule, rails are laid with staggered or broken joints; that is, each joint in one line of rails is opposite the middle of a rail in the other line.

In nearly all joints the main element consists of a pair of splice bars bolted to both rails The old-fashioned flat bars, called *fish plates,* have been abandoned for important work in favor of angle splice bars which can be made more rigid vertically and thus better resist bending Moreover, their flanges give additional lateral stiffness to hold the rails in line. Various attempts have been made to reduce the shock of wheels crossing the small open gap between the rails. In some designs the rail ends have been cut diagonally or halved so as to lap side by side, and in others a high splice bar has been used on the outside of the rail to give a bearing to the wheel. None of these plans has given results that would warrant the expense involved.

Elimination of rail joints by welding the rails to form a continuous bar is impracticable (except with street-railway rails which are protected by being embedded in the pavement) owing to the necessity of providing for the changes in length with changes in temperature However, the number of joints has

been reduced to a large extent by the use of longer rails Thus, with 33-foot rails the number of joints per mile is 320, instead of 352 with 30-foot rails

23. Angle-Bar Rail Joint.—A typical rail joint with angle splice bars is shown in Fig. 3. The shape of the bars varies greatly, and for heavy rails the stiffness of the bar is often increased by ribs or flanges along the top and bottom of the vertical web. In the upper part of the drawing is shown

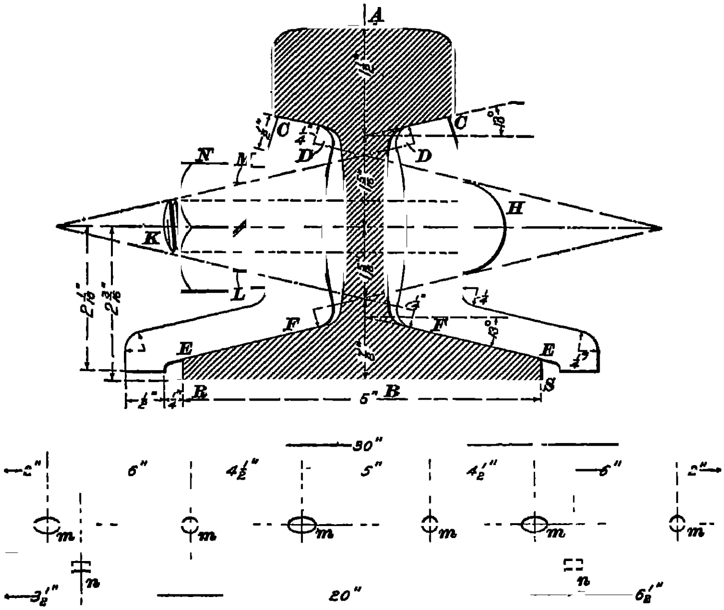


FIG 3

the rail *A B* with two angle bars *C D F E* secured to it by bolts *H K*. The bars are drawn together and held firmly in place by screwing up the nut *N*, which is prevented from working loose by the nut-lock *L M* A side view of a splice bar is shown in the lower part of Fig 3 Some of the bolt holes *m* are oval because one bar of each pair should have holes to fit oval necks on the bolts, which are thus prevented from turni· when the nuts are screwed on. In modern practice, alter···e

bolts have the nuts on opposite sides of the rail, and therefore the bolt holes in the splice bars are alternately oval and round. These holes are also slightly larger than the bolts, to allow movement of the bolts when the rails expand or contract in length because of changes in temperature.

An important requirement of splice bars is that they must make an exact fit against the bottom of the head and the top of the base of the rail. These contact surfaces are inclined, so that as the splice bars are drawn together they are wedged tightly between the head and base of the rail; the angle of inclination, *J* and *K*, Fig 2, is called the *fishing angle* and

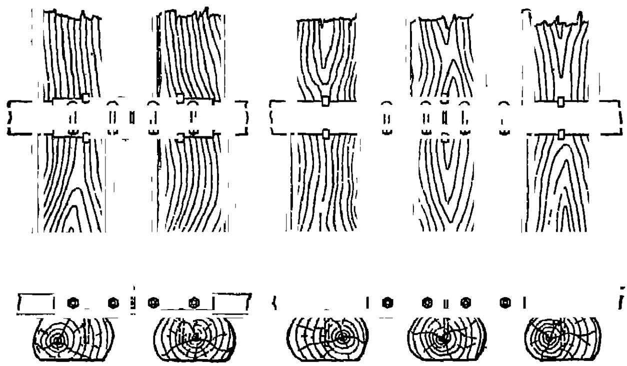
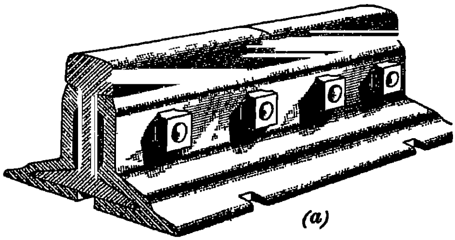


FIG 4

is about 13°. In this way the splice bars add to the stiffness of the joint, as long as they are kept tight, and prevent independent vertical motion of the rail ends Splice bars from 22 to 28 inches long, with four bolts, are generally used, but six-bolt joints with bars from 30 to 36 inches long are also in use In general, the flanges of the bars have notches or slots *n*, Fig. 3, to receive the track spikes, as this arrangement allows slight movement but checks excessive creeping or longitudinal movement of the rails on the ties. However, there is a growing opinion in favor of omitting the slots and using rail anchors in order to relieve the spikes of the longitudinal thrust.

24. Suspended and Supported Joints.—As a rule, the joint comes between two ties called *joint-ties* that are spaced closer together than the intermediate ties. Such an arrange-

ment is termed a *suspended joint* An alternative plan that is used to a limited extent is to place the two rail ends on a tie, making a *supported joint.* A supported joint is likely to make



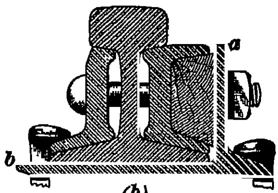


FIG 5

a hard spot in the track, causing more jar to trains than a suspended joint that allows for deflection between the ties Both plans are shown in Fig 4

25. Other Forms of Joints.—Numerous special designs of rail joints are in use, some of which give a bottom support to the rails in a suspended joint, as in Figs 5 and 6. In the continuous joint, shown in Fig 5 (*a*), each splice bar has its flange grooved to receive the rail flange. In the Weber joint, view (*b*), a separate **L**-shaped plate *a b* is used, which rests on the ties and carries the rails. The bolts are long enough to pass through the web of this plate, as well as through the splice bars, and a wood filler is placed between the plate and

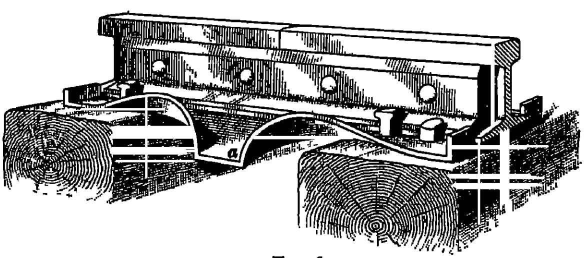


FIG 6

the outer splice bar; this bar is of channel section, as shown Another method is illustrated in the Abbott joint, Fig. 6, in which a separate bridge plate *a* is used under the rails The ends of the plate rest on the joint-ties and its sides are bent

downwards to form stiffening ribs In several special designs of splice-bar joints the flanges of the bars are bent down vertically so as to project below the rail, thus increasing the stiffness of the bar and joint. When rails of different heights or sections are connected, a *step joint,* or *compromise joint,* is used, with forged or malleable cast-iron bars so made that half the length fits one rail and the other half fits the other rail.

26. Bonded and Insulated Joints.—Where electric track circuits are used in connection with signaling, the electric current travels through the rails. Passage of the current across

TABLE IV
EXPANSION SPACES AT RAIL JOINTS

Temperature of Air When Rails Are Laid Degrees F	Length of Rail, in Feet 30 and 33	60
	Expansion Space, in Inches	
0 to 12	$\frac{1}{4}$	$\frac{1}{2}$
12 to 25	$\frac{1}{4}$	$\frac{7}{16}$
25 to 37	$\frac{3}{16}$	$\frac{3}{8}$
37 to 50	$\frac{3}{16}$	$\frac{5}{16}$
50 to 62	$\frac{1}{8}$	$\frac{1}{4}$
62 to 75	$\frac{1}{8}$	$\frac{3}{16}$
75 to 87	$\frac{1}{16}$	$\frac{1}{8}$
87 to 100	$\frac{1}{16}$	$\frac{1}{16}$
Over 100	Close	

the joint is assisted by copper bars or bonds welded to the ends of the two rails or by copper bond wires having their ends fitted to small studs in holes drilled in the rails. At the end of each track circuit the current must be prevented from passing through the joint For this purpose, strips of insulating material are placed between the bearing surfaces of the bars and rails and between the ends of the rails, while sleeves of the same material are fitted over the bolts in the bolt holes

27. Expansion Spacing at Joints.—A 30-foot rail increases or decreases in length about 00234 inch for each

degree Fahrenheit of variation in temperature, and this change in length must be provided for at the joints. Therefore, the rails are not laid in contact, end to end, but are separated by a short space, varying according to the atmospheric temperature when the rails are laid In Table IV the width of opening is given for ordinary and long rails. With 30-foot and 33-foot rails, no opening should exceed ⅜ inch. The spaces for 60-foot rails are double the corresponding values for 30-foot rails, since the rails are twice as long, the spaces for other lengths of rails can be found by interpolation

28. Bolts and Nuts.—Proper service of the rail joint depends largely on the strength and tightness of the bolts; one

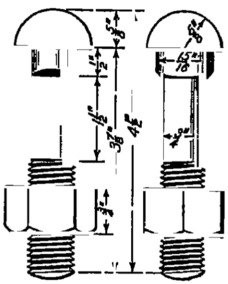


FIG 7

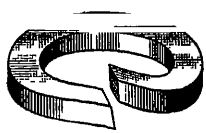


FIG 8

form, with round heads, is shown in Fig. 7. The bolts are usually ⅞ inch or 1 inch in diameter, but 1¼-inch bolts are used for very heavy rails They have round or square heads and square or hexagonal nuts. An oval neck is formed under the head to fit the oval holes in the splice bars.

The vibration and shocks to which the rails are subjected during the passage of trains tend to cause the nuts to work loose. To prevent this a nut-lock is used Usually this device acts as a spring and is placed between the nut and splice bar, as at *L M*, Fig 3 One of the most common forms of nut-locks is a steel ring cut at one side and twisted to a spiral, as shown in Fig 8 As the nut is screwed up, it flattens the ring and causes the two points to press on the under part of the nut on the one side and on the face of the angle plate on the other In turning up the bolt the nut slides easily past the

point Whenever there is any tendency for the nut to turn backwards, the point of the lock bites into the nut and effectively prevents it from turning.

29. Spikes.—Rails are fastened to the ties by steel spikes of square section having hook heads that bear on the rail base An ordinary size of spikes for heavy rails is $\frac{1}{2}$ inch or $\frac{9}{16}$ inch square and $5\frac{1}{2}$ inches long under the head. The lower end tapers on two sides to a chisel edge, as in Fig. 9 (*a*) and (*b*), or has a shorter taper on four sides to form a point as in (*c*). The best spike has a sharp edge or point to cut the wood fibers,

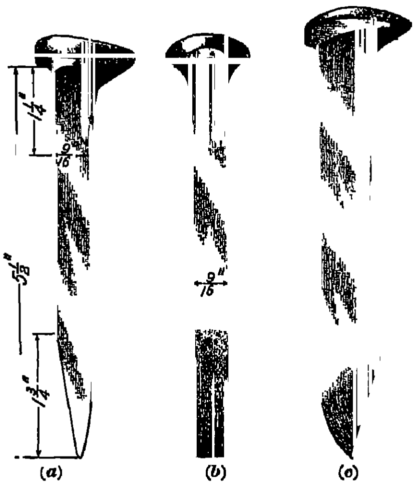


FIG. 9

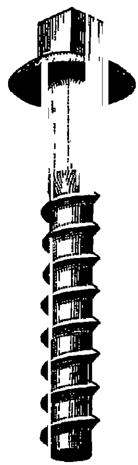


FIG 10

and a smooth body to press back the fibers without tearing and crushing them In this way the fibers pack tightly against the spike and hold it in place, and there is the least chance for water to enter and cause decay.

Extensive use is made also of screw spikes, Fig. 10, the threads of which cut into the sides of the spike hole and so obtain a firm grip in the wood. It is necessary to bore holes in the tie of slightly smaller diameter than the body of the spike. The head of the screw spike may bear directly on the rail flange or upon a clip shaped to rest on the rail flange and the tie or tie-plate.

30. Tie-Plates.—Rails on softwood ties will gradually cut into the wood, and on curves the outer edge of the rail base will cut even into hard wood, as the rail tends to overturn under the lateral pressure of the wheel flanges In this way ties may be so damaged as to require removal long before they decay. To protect the tie against such destructive action, plates of steel, wrought iron, or malleable iron are placed under the rail to distribute the pressure over a large area of the wood and to resist the tendency of the rail to overturn. Many of these plates have projecting lips or ribs on the under side, as in Fig. 11, to bite into the wood and give a secure hold.

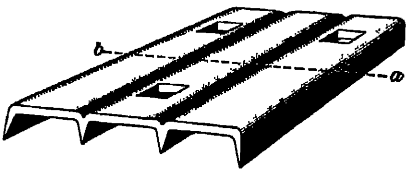


FIG 11

The plates are placed lengthwise on the tie, so that the rail crosses them along the line *a b* The square holes are for the spikes to pass through, two being driven on the outer side of the rail flange and one on the inner, in the form of the plate shown Other forms of plates are made flat in order to avoid any cutting of the wood, and these should be fastened to the tie by spikes separate from those which hold the rails On the upper surface of the plate there is often a rib or shoulder that fits against the outer edge of the rail base, and thus relieves the spikes of some of the lateral pressure tending to displace them. Such a shoulder tie-plate, with a flat bottom is shown in Fig. 12.

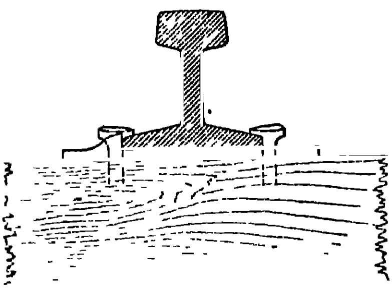


FIG 12

It is important that the tie-plates be placed carefully in proper position by the aid of a gauge or measure, as the spike holes in the plates determine the positions of the rails, and therefore, the width of the track Plates with bottom rib should be driven down flat on the tie, so that dirt and gravel may not get under them and cause them to be

bent or buckled, thus preventing a flat bearing for the rail. The ribs on the plates may be driven into the tie by machine, but if a hand sledge or maul is used, a wood striking-block should be placed on the plate so that it will not be bent by the blows.

31. Rail Braces.—On curves, the wheel flanges exert a strong lateral pressure against the rails, tending to force them outwards or to overturn them As the resistance of the spikes is not sufficient to prevent this overturning, rail braces are spiked to the tie Of the two rail braces shown in Fig 13, the one at the left bears only against the rail web while the other bears against both the web and the head. These braces are usually required on the outside of both outer and inner rails, as the wheels of fast trains exert pressure mainly against the outer rail of the curve, while those of slow heavy trains

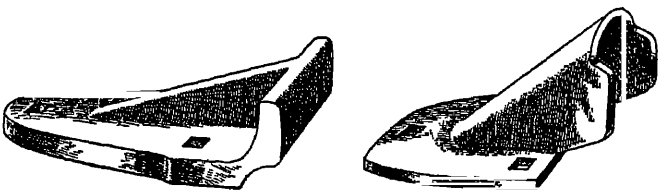
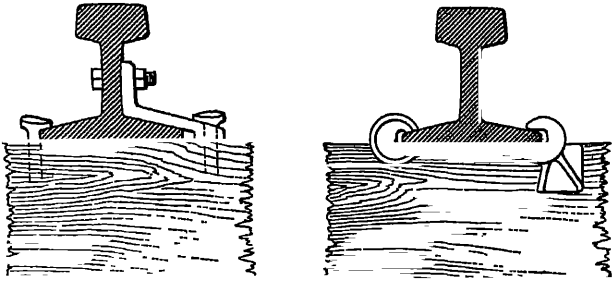


FIG 13

bear heavily against the inner rail Rail braces are often used also to support guard-rails at frogs, as these rails have to hold each wheel against the track rails in order that the opposite wheel on the same axle will be in line to pass through the frog properly These braces are frequently made of cast iron, but the best forms are of malleable iron or else are stamped and punched from wrought-iron plates by special machines.

32. Rail Anchors.—Due to the rolling effect of wheels on grades and soft ground, the rails have a tendency to creep or move longitudinally along the ties Such movements may cause considerable trouble at switches, frogs, and crossings Creeping is resisted to best advantage by holding each rail, rather than by holding or anchoring the rails at long intervals. In one type of an anchor, shown in Fig. 14 (*a*), an angle-shaped piece of steel has one leg bolted to the rail web and the other leg spiked to the tie, or this lower leg may be long enough

to rest on two ties Another type, in more general use, is a clamp fitted to the bottom of the rail and bearing against the side of the tie, as shown in (*b*). Any tendency of the rail to



(*a*) (*b*)

FIG 14

move increases the grip of the clamp. On single track it may be necessary to anchor the rail against movement in both directions.

COST AND QUANTITIES OF TRACK MATERIALS

33. Cost Figures.—Prices of materials vary frequently and depend largely on the locality and on market conditions. With any material, also, the price or first cost is only a part of the expense represented by the material when finally put in service in the track Inspection, transportation, and placing all add their share to the total cost

34. Ballast.—The quality, quantity, and cost of ballast must be in proportion to the traffic Cheap and inferior ballast on track carrying heavy traffic will not only require continual work and expense for track maintenance, but will have a direct, though indefinite, influence in increasing operating expenses by greater fuel consumption and repairs to rolling stock In general, the total expense for ballast in track depends on 1, the first cost of the material as received by the railway; 2, the distance the material must be hauled, 3, the method of handling the material Thus, if ballast is shoveled from cars its cost will be much greater than if it is dumped or deposited in place by ballast cars.

The quantity of ballast varies with the cross-section. On single track it ranges from 1,000 cubic yards per mile for light ballasting on new lines of very small traffic to 2,630 and 3,800 cubic yards per mile for depths of 8 inches and 12 inches, respectively On double track the quantity may be from 5,130 cubic yards for a depth of 8 inches to 7,300 cubic yards for a 12-inch depth

35. Ties.—The total cost of a tie in the track includes initial cost, inspection, freight, placing, fastenings, and supervision; also, perhaps, preservative treatment and tie-plates.

TABLE V

NUMBER OF TIES PER MILE

Spacing of Ties Center to Center	Number of Ties per Rail	Number of Ties per Mile
30-Foot Rail		
1 ft 6 in.	20	3,520
1 ft 8 in.	18	3,168
1 ft. 10½ in	16	2,816
2 ft.	15	2,640
2 ft. 1¾ in.	14	2,464
2 ft. 6 in.	12	2,112
33-Foot Rail		
1 ft. 10 in.	18	2,880
1 ft. 8 in.	20	3,200

Treatment may be estimated at 50 cents per tie for creosoting and 25 cents for the zinc-chloride process. On main track, there are usually from 16 to 18 ties to each 30-foot rail, while 14 ties per rail are used on branch lines. The number of ties per mile for different spacings is given in Table V.

36. Rails.—The market price of rails varies from as low as $22 per gross ton of 2,240 pounds to as high as $48. In 1922 it averaged $43. For a given weight of rail, the number of gross tons per mile of single track can be obtained from Table VI, but these figures should be increased by 1 or 2

per cent to allow for waste in cutting. The rule for obtaining the number of gross tons per mile of single track is to multiply the weight of rail in pounds per yard by 11 and

TABLE VI

WEIGHT OF RAILS PER MILE OF TRACK

Weight of Rail per Yard Pounds	Weight of Rails per Mile of Track Tons	Pounds
40	62	1,920
50	78	1,280
60	94	640
65	102	320
70	110	
75	117	1,920
80	125	1,600
85	133	1,280
90	141	960
95	149	640
100	157	320
120	188	1,280

divide the product by 7 Thus, from Table VI, for 80-pound rails the weight per mile is 125 tons+1,600 pounds, or 125.7 tons; and by the rule, the weight is $80 \times \frac{11}{7} = 125\ 7$ tons

EXAMPLE —Track is laid with 80-pound rails Find the cost of rails per mile of track if the price is $40 per ton and 2 per cent is allowed for waste

SOLUTION —From Table VI the weight of rails per mile is 125 T + 1,600 lb =125 71 T When 2 per cent is allowed for waste, the total weight required is 125 71×1 02=128 22 T Hence, the cost is 128 22 ×40=$5,129 Ans

37. Splice Bars and Bolts.—Angle bars and track bolts are usually sold by the pound, but for some of the patented forms of rail joints the price per pair is quoted. The weight of bars varies widely with the size and the form of section

Bolts are put up in kegs of about 200 pounds, the average

number of bolts of different sizes in each keg being given in Table VII. In Table VIII are given the number of pairs of

TABLE VII
NUMBER OF TRACK BOLTS IN A 200-POUND KEG

Size of Bolt Inches	Thickness of Nut Inch	Width of Nut over Faces Inches	Bolts per Keg Square Nuts	Bolts per Keg Hexagonal Nuts
$\frac{3}{4}\times4$	$\frac{3}{4}$	$1\frac{1}{4}$	245	256
$\frac{7}{8}\times4\frac{1}{2}$	$\frac{7}{8}$	$1\frac{7}{16}$	159	166
$1\times4\frac{1}{2}$	1	$1\frac{5}{8}$	120	126
1×5	1	$1\frac{5}{8}$	112	117

angle bars and the number of bolts per mile of track for different rail lengths The weights of splice bars per foot for

TABLE VIII
RAILS, SPLICE BARS, AND BOLTS PER MILE OF TRACK

Length of Rail Feet	Number of Rails per Mile	Number of Pairs of Angle Bars	Number of Bolts, Four to Each Joint	Number of Bolts, Six to Each Joint
18	587	587	2,348	3,522
20	528	528	2,112	3,168
21	503	503	2,012	3,018
22	480	480	1,920	2,880
24	440	440	1,760	2,640
25	422	422	1,688	2,532
26	406	406	1,624	2,436
27	391	391	1,564	2,346
28	377	377	1,508	2,262
30	352	352	1,408	2,112
33	320	320	1,280	1,920
60	176	176	704	1,056

different weights of rails are approximately as follows $8\frac{1}{2}$ pounds for 60-pound rails, $10\frac{3}{4}$ for 75-pound rails; $11\frac{1}{2}$ to 13

for 80-pound rails, 13½ to 17 for 90-pound rails; and 16 to 20 pounds for 100-pound rails For a given pattern of splice bars and a given size of bolts, the number and total weight of the bars and bolts per mile of single track can be found by means of Tables VII and VIII

EXAMPLE—For 30-foot rails the angle bars weigh 70 pounds per pair and have six bolts ¾ in ×4 in, with square nuts The prices are 2 4 cents per pound for the bars and $6 per keg for bolts Find the cost of (*a*) angle bars, and (*b*) bolts per mile of track

SOLUTION—(*a*) Table VIII gives 352 pairs of angle bars for 30-foot rails, with 2,112 bolts The weight of the bars is 352×70=24,640 lb, and the cost is 24,640× 024=$591 36 Ans

(*b*) Table VII gives 245 bolts per keg, and the number of kegs is 2,112÷245=8 6 Hence the cost is 8 6×6=$51 60 Ans

38. Spikes.—The approximate number of spikes per keg of 200 pounds is given in Table IX for different sizes The

TABLE IX

SPIKES PER MILE OF TRACK

Size of Spike Under Head Inches	Average Number per 200-Pound Keg	Number of Spikes per Mile with 2,640 Ties and Four Spikes to Each Tie is 10,560	
		Average Weight Pounds	Average Number of Kegs
½×4	600	3,520	17 6
½×4½	536	3,940	19 7
½×5	490	4,320	21 6
$\frac{9}{16}$×5½	340	6,220	31 1
⅝×6	265	7,960	39 8

weight of the spikes and the number of kegs per mile are also given for ties spaced 2 feet between centers

EXAMPLES FOR PRACTICE

1. Track is laid with 90-pound rails If 1½ per cent is allowed for waste, and the price is $36 per ton, what is the cost of the rails per mile of track? Ans $5,168

2 The rails in a track are 33 feet long, the angle bars weigh 80 pounds per pair, and at each joint there are six bolts 1 in $\times 4\frac{1}{2}$ in with square nuts If the bars cost 2 4 cents per pound and the bolts $6 per keg, what is the cost per mile of track of (*a*) the angle bars and (*b*) the bolts?

Ans $\begin{cases} (a)\ \$614\ 40 \\ (b)\ \$96 \end{cases}$

TRACK CONSTRUCTION

GENERAL METHODS OF LAYING TRACK

39. Handling Material.—For a new line, the track material is stored at the beginning of the line and forwarded to the front or *head of steel* on trains of flat cars If a locomotive crane is at the front end of the train, the first cars are loaded with rails, the next car carries fastenings, and the other cars have ties At the front the ties are loaded into wagons for distribution ahead As the ties are placed on the roadbed the rails are taken from the car by the crane and placed on the ties, the train moving forwards as soon as each length of rails is fastened to the ties and spliced For double tracking much of the material can be delivered from cars on the existing line, the handling of this work being arranged so as not to interfere with the regular traffic

40. Preparing Subgrade.—Before laying the track the surface of the roadbed should be filled or leveled to grade and finished either flat or with a drainage slope of about 1 in 24 on each side from the center line

41. Distributing and Placing Ties.—As the wagons hauling the ties move forwards, the ties are thrown off and carried to place. The larger ties are used at the joints, which are marked by small stakes The ties must be laid far enough in advance to be clear of the rail-laying, but if they are laid for too great a distance ahead there is likely to be much shifting of the joint-ties to fit the rail joints Stakes marking the center line of track are driven 100 feet apart on tangents and 50 feet apart on curves, when the degree of curve is less than 12°, for sharper curves, the stakes are 25 feet apart A tack

in the head of the stake marks the center line A tie line stretched between stakes driven at the proper distance from the center stakes marks the location of the ends of the ties Care must be taken to place the ties at right angles to the center line, as, if laid askew, they will not hold the rails in the proper position.

The distance between the centers of ties varies from 18 inches to 2 feet in main track, and sometimes to 30 inches in sidings Because of the difficulty of tamping under the ties, they should not be placed closer together than about 18 inches between centers, even then such a spacing can hardly be adopted unless the ties are small, since the clear space between the ties will be so narrow that good tamping will be impracticable On the other hand, even with the largest ties that are ordinarily used, a spacing greater than 2 feet between centers will make too long a span for the rails in track carrying ordinary traffic. However, ties are not usually spaced with exact uniformity Since it has been generally held that the joints should have a little better support, the ties are usually adjusted so that those under the joints are spaced a little closer than the others But there is an increasing tendency to disregard the position of rail joints in spacing the ties.

42. Handling and Placing Rails.—Formerly rails were loaded and unloaded at the storage yard by hand; large gangs of men were required, and great care was necessary to prevent damage to the rails when they were dropped from cars Now this work is generally done by some form of power hoist and crane, requiring only a few men and reducing the damage to the rails In tracklaying, the rails are either slid into place by inclined chutes with rollers in the bottom or are placed by a crane at the head of the train In case rails are bent in handling they should be carefully straightened before being placed in straight track Straightening or bending rails by hammering with sledges should not be allowed, as it is likely to cause damage that will result in fracture of the rail in the track The form of the rail bender commonly used will be described later

43. Gauging Track.—The distance between the gauge sides of the heads of opposite rails is called the *gauge* of a track. On straight track, a uniform gauge must be maintained. Usually the right-hand rail is first lined and spiked and then

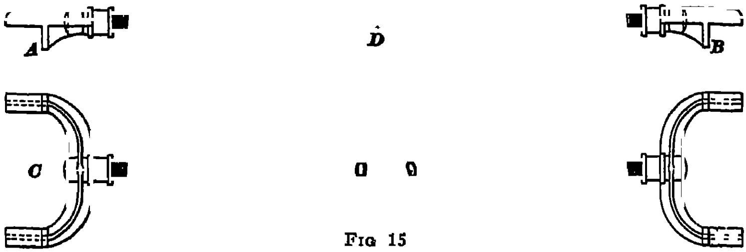


FIG 15

the other rail is brought into position by a track gauge, one form of which is shown in Fig 15 A bar or pipe has at each end a **U**-shaped casting with lugs *A* and *B* The distance between these lugs on the castings *C* is the gauge of track, and a line between the two lugs on each side will be at right angles to the bar. The bar is placed on the line rail with both lugs tight against the inside of the rail head. The other rail is pushed against the two lugs on the other end of the bar and is then spiked in place. A notch *D* on the bar marks the center of the track.

44. Spiking Rails.—As the rails are laid they are spiked first to the joint-ties and two or three intermediate ties. Spikes should be driven vertically and with the body in contact with the rail base It is poor work to drive a spike in a slanting position or to place it at a little distance from the rail and then bend the head so as to give the track the proper gauge The proper position for the spikes is from 2½ to 3 inches from the sides of the tie, as shown in Fig 16. If in the center of the tie and opposite each other, they are likely to split the wood

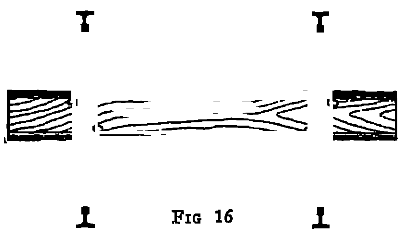


FIG 16

45. Allowance for Rail Expansion.—In laying rails, provision must be made for expansion and contraction As the temperature rises the rails lengthen, and unless sufficient space is left between their ends they may press together with such force as to bend the rails or buckle the track If there is too great a space, so that the holes in the splice bars are tight against the bolts, these bolts may be sheared or broken by the shortening or contraction of the rails due to severe cold. Proper spacing to be used in laying rails at different temperatures has been given in Table IV To provide this spacing, steel expansion shims of proper thickness are placed between the ends of the rails as they are laid These are usually angular, as shown in Fig. 17, with two legs of different thicknesses for two different temperatures. The thickness should be stamped on each piece. As a rail is laid a shim is dropped into the joint and the rail pushed against it. The shim should remain in place until the joint is fully bolted.

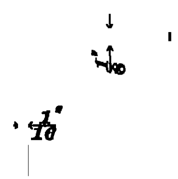


FIG 17

46. Ballasting. After the ties have been placed on a proper subgrade and the rails laid and fastened, the ballast is distributed from a train of flat cars or dump cars on the new track, but the train should move only at low speed The track is then raised by jacks to bring the ties from 4 to 6 inches above the subgrade, and the ballast is shoveled and tamped under the ties The process is repeated until the required depth of ballast is obtained. For this work grade stakes are set and marked to indicate the grade of the top of the rail in the finished track Grade stakes should be placed at intervals of about 16 feet. A straightedge placed on these stakes marks the grade for the intervening points

The placing of grade stakes so close together is contrary to common practice, but the increased labor by the engineer is more than compensated for by the saving of the time ordinarily consumed in sighting when grade stakes are set at inter-

vals of 50 or 100 feet. The surface will be better where a straightedge can be brought into use, and the danger of kinking rails or bending them out of surface is obviated

47. Ballast Cross-Section.—Stone or washed-gravel ballast is usually filled in level with the tops of the ties and

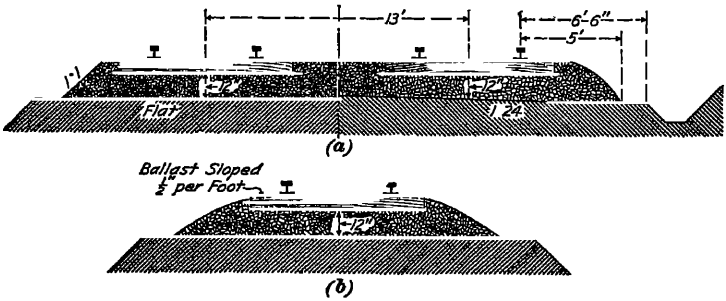


FIG 18

extended as a shoulder about 1 foot beyond their ends and then sloped down to the subgrade, as shown on the left side in Fig. 18 (*a*), but sometimes it is rounded off from the ends of the ties, as shown on the right side. Ordinary gravel, however, is usually sloped from the middle of the track to about 2 or 3 inches below the tops of the ties at their ends, so as to be clear of the rail base as shown in (*b*). This allows water to

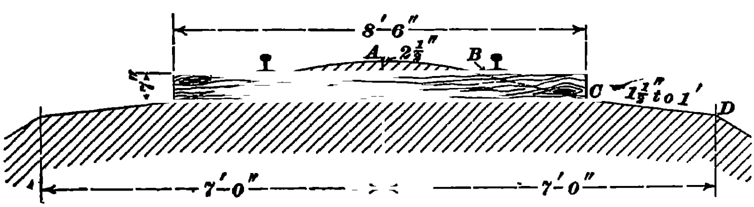


FIG 19

drain away rapidly as it does not percolate through gravel so freely as through broken stone. Sand is sometimes finished level with the tops of the ties, as it drains readily With earth ballast or cementing gravel which gives very poor drainage, the ballast is filled in about 2½ inches above the ties at the center, as shown at *A*, Fig. 19, and is then sloped to pass

under the rails at B and reach the bottom of the ties at their ends, in order to give a steep slope to carry off the water Beyond the ties there is a sloping shoulder $C\,D$ to the edge of the embankment or ditch With this arrangement the ballast has very little hold on the tie, and, consequently, the track is not suitable for high speeds

LAYING CURVED TRACK

48. Curve Ordinates.—As previously explained, the center line of curved track is marked by stakes at intervals of

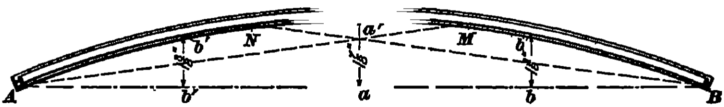


FIG 20

25 or 50 feet and the positions of the rails at these points can be readily determined by means of a track gauge The rails must be bent to form a smooth curve and their positions between stakes are best found by measuring ordinates from chords.

The *middle ordinate* of a curve for a given chord length is the perpendicular distance from the middle point of the chord to the curve Thus, the middle ordinate of the curved rail AB, Fig 20, is the distance $a\,a'$ from the middle point of the line joining the gauge sides of the rail head at A and B to the gauge side at a'. The value of the middle ordinate of a circular curve can be calculated closely by means of the formula

$$m=\frac{c^2}{8R} \qquad (1)$$

in which m = middle ordinate, in feet;
c = length of rail, in feet;
and R = radius of curve, in feet

The middle ordinates in inches for various lengths of rail and degrees of curve are given in Table X.

The perpendicular distances from the chord to the curve at the quarter points are called *quarter ordinates* Thus, in Fig. 20, Ab' and Bb are each equal to $\frac{1}{4}$ AB and the distances

$b'b'$ and bb are the quarter ordinates for the length of rail AB. The quarter ordinates are always equal to three-fourths of the length of the middle ordinate, if q is the quarter ordinate,

$$q = \tfrac{3}{4}m \qquad \textbf{(2)}$$

EXAMPLE.—Find the middle and quarter ordinates of a 30-foot rail for an 8° curve

SOLUTION.—The radius of an 8° curve is 716 78 ft By formula **1**,

$$m = \frac{30^2}{8 \times 716\ 78} = \frac{900}{5{,}734\ 24} = 157 \text{ ft.} = 1\tfrac{7}{8} \text{ in. Ans.}$$

By formula **2**, $q = \frac{3}{4} \times 1\frac{7}{8} = 1\frac{13}{32}$ in, or, say $1\frac{3}{8}$ in Ans.

TABLE X

MIDDLE ORDINATES FOR CURVING RAILS

Degree of Curve	Length of Rail, in Feet					
	30	28	26	24	22	20
	Middle Ordinate, in Inches					
1	1/4	3/16	3/16	3/16	1/8	1/8
2	1/2	7/16	3/8	5/16	1/4	3/16
3	11/16	5/8	9/16	7/16	3/8	5/16
4	15/16	13/16	11/16	5/8	1/2	7/16
5	1 3/16	1 1/16	7/8	3/4	5/8	9/16
6	1 7/16	1 1/4	1 1/16	7/8	3/4	5/8
7	1 5/8	1 7/16	1 1/4	1 1/16	7/8	3/4
8	1 7/8	1 5/8	1 7/16	1 3/16	1	7/8
9	2 1/8	1 7/8	1 5/8	1 3/8	1 1/8	15/16
10	2 3/8	2 1/16	1 3/4	1 1/2	1 1/4	1 1/16
11	2 5/8	2 1/4	1 15/16	1 11/16	1 3/8	1 1/8
12	2 13/16	2 1/2	2 1/8	1 13/16	1 9/16	1 1/4
13	3 1/16	2 11/16	2 5/16	1 15/16	1 5/8	1 3/8
14	3 5/16	2 7/8	2 1/2	2 1/8	1 3/4	1 1/2
15	3 9/16	3 1/16	2 11/16	2 1/4	1 15/16	1 9/16
16	3 3/4	3 1/4	2 13/16	2 3/8	2 1/16	1 11/16
17	4	3 1/2	3	2 9/16	2 3/16	1 3/4
18	4 3/16	3 11/16	3 3/16	2 11/16	2 5/16	1 7/8
19	4 7/16	3 7/8	3 3/8	2 7/8	2 7/16	2
20	4 11/16	4 1/8	3 9/16	3	2 9/16	2 1/8

49. Curving Rails.—For tracklaying, the rails are usually curved at the storage yard by means of a roller bender, the rails being pulled through by a cable or the rolls being driven by power For bending rails on the work and also for straightening kinked rails, a screw bender, or *jim crow,* is generally used. This device, Fig. 21, consists of a heavy **U**-shaped frame with hooked ends *a* and *b* that fit over the head of the rail. Through the end of the frame, at *c,* passes the end of a screw *d,* the opposite end of which is supported by the guide *e.* By the long-handled wrench *f* the rail is forced outwards

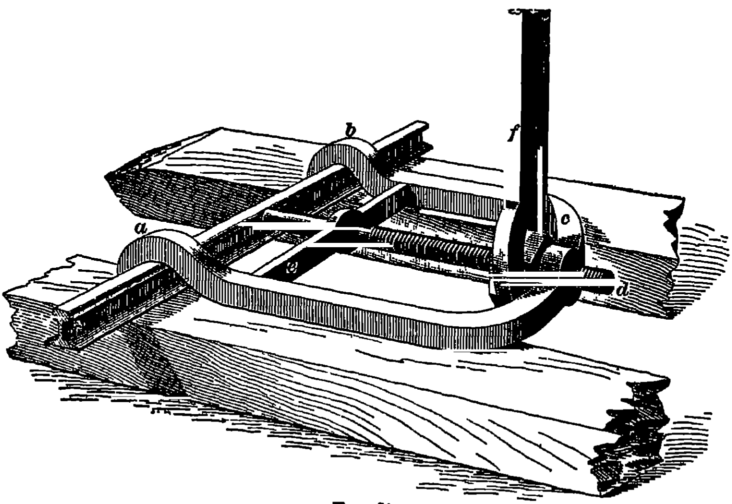


FIG 21

between the hooks to the amount required The bender is shifted along the rail to curve it from end to end

If the end *A* is correctly located, the rail *AB,* Fig. 20, can be laid to the proper curvature by stretching a string from the gauge sides of the rail head at *A* and *B* and making the middle and quarter ordinates equal to the calculated values For sharp curves or for long rails, it is usually better to curve part of the rail, about 20 feet long, by stretching the string between *A* and *M,* and then to shape the remainder by holding the string between *N* and *B*

50. Widening Gauge on Curves.—In traveling on curved track the car wheels tend to ride hard against the outer rail because the line of wheelbase forms a chord with the rail instead of being parallel to it As the axles remain parallel with each other and cannot be radial to the curve, there is a slipping and lateral sliding action of the wheels. The pressure against the rails may be resisted by rail braces, as described, but to make the cars ride easily, the gauge of track is widened on sharp curves. This widening may be $\frac{1}{8}$ inch for each 2 degrees, beginning with 9 degrees and reaching a maximum of $\frac{3}{4}$ inch for curves of 19 and 20 degrees For example, on an 18° curve, the widening is $\frac{18-8}{2}\times\frac{1}{8}=\frac{5}{8}$ inch. When a guard-rail is placed on straight track, its head should be $1\frac{3}{4}$ inches from that of the track rail, but on curves where the gauge is widened, this space must be increased by the amount of gauge widening On curves a special form of track gauge is used to show the proper widening due to curvature

51. Length of Inner and Outer Rails.—Since the radius of the outer rail on a curve is greater than that of the inner rail, the length of the former must also be greater. For this reason, a number of rails 6 inches or 2 feet shorter than the standard length are supplied on the tracklaying train for use in the inner side of curves in order to maintain the joints in their proper positions relative to those in the outer rail These short rails must be laid in proper order to insure correct positions of the joints. In general one $29\frac{1}{2}$ foot rail per 100 feet will be used for each 6 degrees of curvature This difference in length between the inner and outer rails of a track may be determined by one of the two following rules, the first one being for light curves laid to standard gauge and the second for sharp curves with widened gauge

Rule I.—*Multiply the degree of the curve by the length in stations of 100 feet, and this product by $1\frac{1}{32}$; the result will be the difference in length between the inner and the outer rail, in inches.*

Rule II.—*Multiply the distance between the center lines of the rails by the length of the curve, in feet, and divide the product by the radius of the track curve; the quotient is the required difference in length, expressed in feet*

EXAMPLE 1—The degree of a curve is 4° and the length is 520 feet What is the difference in length between the inner and outer rails of the curve?

SOLUTION—Since the curvature is less than 9°, the standard gauge is used and rule I applies The length of the curve in stations of 100 ft is 5.2 Then the difference in length between the rails is $4 \times 5.2 \times 1\frac{1}{32} = 21.45$ in $= 1.788$ ft Ans

EXAMPLE 2—A 15° curve is 387 feet in length If 100-pound A R E A rails are used, find the difference in length between the inner and outer rails

SOLUTION—The curvature is greater than 9° and, therefore, the gauge must be widened. The difference between 15° and 8° is 7°; since the widening is $\frac{1}{8}$ in for each 2°, it is $\frac{1}{2}$ in for 7°. The width of the head of a 100-lb A R E A rail is found from Table III to be $2\frac{11}{16}$ in Hence, the distance between the center lines of rails is 4 ft $8\frac{1}{2}$ in $+2\frac{11}{16}$ in $+\frac{1}{2}$ in $=4$ ft $11\frac{11}{16}$ in $=4.974$ ft The radius of a 15° curve is 383.06 ft Then, by rule II, the difference in length of rails is

$$\frac{4.974 \times 387}{383.06} = 5.025 \text{ ft} \quad \text{Ans}$$

52. Superelevation on Curves.—On curved track the outer rail must be elevated above the inner rail, a track level being used to give the proper superelevation As shown in Fig. 22,

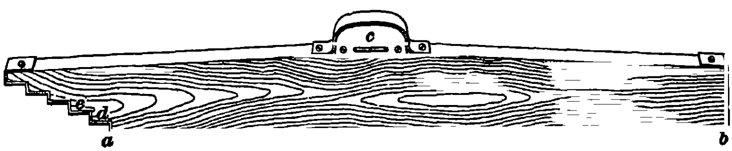


FIG 22

this device consists of a straightedge *a b* with $\frac{1}{2}$-inch steps *d* and *e* at one end, and a spirit level *c* to indicate when the edge *a b* is horizontal On straight track the edge *a b* is placed on both rails and the bubble of the spirit level is brought to the center of the tube For a curved track with a superelevation of 1 inch, the end *b* is laid on the inner rail, and the second step *e* is placed on the outer rail; then the bubble is centered by adjusting the height of the outer rail.

A cross-section on curved track is shown in Fig 23. The subgrade is finished level, but the depth of ballast below the

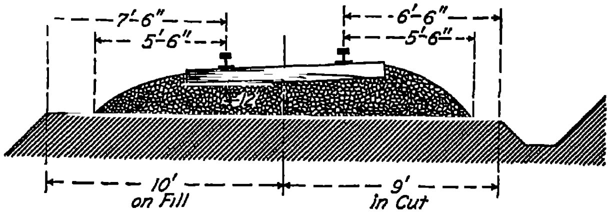


FIG 23

ties is made 12 inches under the inner rail, and the ties are sloped so that the outer rail has the proper superelevation.

EXAMPLES FOR PRACTICE

1 Find the difference in length between the inner and outer rails of a 3° curve 1,480 feet long — Ans 3 816 ft.

2 The rails on a 12° curve, 220 feet long, are 120-pound A R E A. sections Find. (*a*) the widening of the gauge, and (*b*) the difference in length of the inner and outer rails

Ans { (*a*) ¼ in.
(*b*) 2 290 ft

3 By formulas **1** and **2**, Art **48**, and also by Table X, find the middle and quarter ordinates to the following rails (*a*) Rail length is 20 feet, degree of curve is 10°. (*b*) Rail length is 30 feet; degree of curve is 6°

Ans { (*a*) By formulas: $a\,a'$ is 1 05 in, $b\,b$ is 79 in
By Table X $a\,a'$ is $1\frac{1}{16}$ in, $b\,b$ is $\frac{13}{16}$ in
(*b*) By formulas $a\,a'$ is 1 41 in; $b\,b$ is 1 06 in
By Table X $a\,a'$ is $1\frac{7}{16}$ in; $b\,b$ is $1\frac{1}{16}$ in

MAINTENANCE OF TRACK

53. Definition.—Maintenance work includes keeping the track in line and surface, with bolts and spikes tight, ballast properly tamped and shaped, and other parts in proper condition It includes also the replacing of worn or defective material, and the general care or policing of track

54. Shimming.—Track that is badly drained or has poor ballast will heave in winter owing to the action of frost in the roadbed or ballast In order to make a regular surface, the

heights of the rails are adjusted by placing shims between the rails and the low ties These shims are pieces of hardwood of uniform thickness, cut in different sizes from ¼ inch upwards. A spike hole is bored in each shim in order to prevent splitting. The shimming must be carried far enough on each side of the high spot to give an easy grade If the track continues to heave, additional shims must be placed.

In case the required height of shims is over ½ inch, the thin shims must be replaced with thicker ones; long spikes also should be used and rail braces placed outside the rails. Care must be taken to maintain shimmed track in gauge, surface, and line. During a thaw and when the frost is leaving the ground the shims should be removed gradually, the upper ones being taken out first. As soon as the frost is gone for the season and the water has drained from the roadbed, all the shims are removed.

55. Surfacing.—As traffic causes the track to settle at certain points, the low spots must be brought up to grade. For

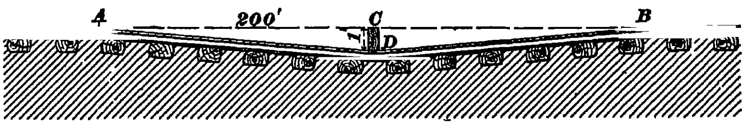


FIG 24

this work the spikes and bolts must first be made tight. Then part of the ballast is removed from between the ties, the track is raised by jacks to the proper level and the ballast is tamped firmly under the ties. Surfacing *out of a face* means surfacing the track continuously over a certain length instead of at isolated spots This should be done on about one-fourth of each track section annually, so that the entire section will be gone over once every 4 years

When a large depression, or sag, occurs in the track, it may be necessary to place additional ballast To find the amount required, a stake is driven at the lowest point *C*, Fig. 24, with its top in line with the normal track surface at *A* and *B*. The volume of ballast in cubic feet is equal to the product of one-half the distance *AB*, the top width of the embankment, and

the height CD of the stake above the rail To find the volume in cubic yards, this product is divided by 27 For example, if the distance AB, Fig. 24, is 200 feet, the top width is 14 feet, and the height CD is 1 foot, the material required to fill the depression is $\frac{200}{2} \times 14 \times 1 \times \frac{1}{27} = 52$ cubic yards.

56. Raising Track.—When the new material has been placed between the rails, the track is raised to the proper grade by the use of a sighting board. Sighting by eye alone is not good practice on a main track. The sighting board is 1 in $\times$4 in. and 5 feet long and has two notches 3 inches deep to fit over the rails. It is placed across the track to be raised at a point about eight or ten rail lengths ahead of the point where the raising is to begin and is shimmed up so that its top is level and at the elevation to which the rail is to be lifted. This position is determined by sighting from the top of the fixed rail at one end of the depression to the fixed rail at the other end and bringing the top of the sighting board to the grade between them. Then the foreman takes his position 50 to 75 feet behind the track which is being raised and sights from the fixed track to the sighting board The intervening track is raised to the desired height by using two jacks under each rail, a heavy one at the joint and a light one at the center. A rail center should not be raised until the jack is in place at the next joint The two jacks on each rail and the two opposite rails are then raised together, the two sides being kept at the same level by means of a track level This prevents the bending of the rails and insures a smooth surface. When the sighting board is reached, it is removed and the track is brought to the proper height by sighting along the rails.

57. Surfacing on Curves.—Special care must be taken to maintain curved track in good condition, as low spots will cause the cars to lurch heavily to the low side The superelevation of the outer rail must be kept accurate and uniform

58. Lining Track.—After the track has been brought to grade, it should be lined up from the engineer's center stakes

by means of the track gauge For ordinary maintenance work straight track may be lined by sighting, as follows: With both rails firmly spiked to gauge, one line of rails is taken as the line rail The foreman sighting along this rail can readily detect swings or irregularities, which are corrected by the men shifting the rail and track by means of lining bars. With his back to the sun and with pebbles placed on the line rail at intervals, the foreman can straighten the track by sighting After taking out the long swings by sighting from as great a distance as his eyesight permits, the foreman stands from 60 to 90 feet away to direct the men in removing the smaller irregularities.

59. Lining Curves.—Curves that are irregular or badly out of line should be reset by the engineer, but in ordinary

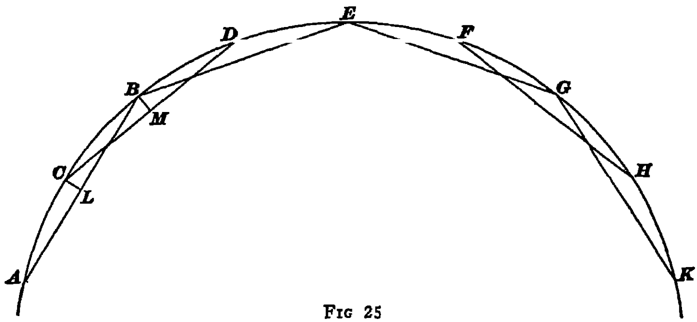


FIG 25

work lining by means of a cord will give good results. This method is shown in Fig. 25 A stretch of 60 feet of curve that appears to be in good line is selected and center stakes are accurately placed at the ends A and B and midway between them at C A cord is stretched between A and B and the distance from C to its middle point L is measured. The distance CL is the middle ordinate for a 60-foot chord The middle point is marked on the cord and the end of the cord is moved from A to C Then the cord is stretched from C in such a direction that the ordinate from the middle point M to B is equal to the middle ordinate CL The other end of the cord locates the track center at D If the center of the track

is not at D, the track is shifted The end of the cord is then moved to B, the middle ordinate is measured from D, and the next point on the center of track is located at E. This method can be used only for circular curves, line for a transition curve must be given by the engineer.

60. Renewing Ties.—The life of ties is so variable, even for ties of the same species and the same lot, that renewals have to be made of occasional ties rather than of all the ties on a stretch of track. Tie renewals average 350 per mile per year for untreated ties and 200 for treated ties Careful inspection of track is made in the fall, and ties bad enough to need renewal are marked The foreman's marking and estimates may be checked by the roadmaster, to provide against excessive removal, which would result in high cost and additional work in restoring the track to its normal condition. New ties are distributed usually from trains and are piled beside the track to be carried to place by the section cars when required. With a mixed lot of ties the hardwood and larger ties may be unloaded at curves and the softwood ties on straight line. Before the work is undertaken the track should be put in good line and gauge

To renew a tie, the spikes are removed and those on the next two or three are loosened, the rails being then raised slightly on these ties by means of a bar and held up by placing wedges or spikes under the rail base The ballast on each side of the tie is loosened, and the tie is pulled out. After the old bed is leveled, the new tie is slipped into place, the rail is lowered upon it, and the tie is held up to the rail by bars while the spikes are being driven Finally, the tamping is finished and the spikes of the adjacent ties are driven down If ties are renewed during the surfacing of the track, the spikes may be drawn from all bad ties, in a rail length and the track then jacked up while the poor ties are removed and new ones put in place

61. Renewing Rails.—New rails being distributed along the track should not be thrown off the car, but slid down skids or lowered by a crane or hoisting device The new rails may

be put in place one at a time, or they may be loosely bolted up in strings placed along the ends of the ties. The former method is used as a rule where traffic is heavy and where track cannot be closed to traffic With the second method, during a long interval between trains or with the track temporarily closed to traffic, a corresponding stretch of old rail is unspiked and shifted toward the middle of the ties. After the rail seats have been dressed to an even surface, and the old spike holes plugged, the string of new rails is thrown into place with bars, the joints are adjusted, and the rails are lined and spiked in place. Expansion shims are placed between the rail ends in the string of new rails to insure the proper joint spacing.

62. Renewing Ballast.—When track is to be newly ballasted, the old material between and outside the ties should be removed and used to widen the shoulder of the roadbed. A layer of old stone ballast, however, may be cleaned by handling with forks and then put back again. A layer of ballast is plowed or dumped from cars and the track is raised by jacks to allow this material to be tamped under the ties

63. General Care of Track.—Besides keeping the track and ditches in good condition, some attention must be given to the appearance of the track and the right of way. Weeds must be removed from the ballast since they interfere with its proper drainage; grass, weeds, and brush on the right of way should be cut; and the roadbed shoulder should be trimmed and kept clear. Old ties and scrap iron must be picked up and disposed of as required, the scrap being stored conveniently outside the section houses ready for delivery to a work train.

64. Track Inspection.—On main lines, one of the section men walks over the entire length of the section every day, to see that the track is in safe condition The foreman is required to go over his section at least once a week, and the roadmaster or supervisor goes over his division at least once a month. The division engineer makes an inspection each spring and fall, examining the track, bridges, and culverts, the drainage of cuts and roadbed, and the general condition of the railway.

TRACKWORK

(PART 2)

TURNOUTS

SWITCHES AND FROGS

SWITCHES

1. Introduction.—Since the wheels of trains are flanged on the inner side in order to hold them on the rails, a special arrangement is necessary to divert and guide the wheels from one track to another. This diversion or transfer is effected by a *turnout* connecting the two tracks, as shown in Fig. 1, in which MN represents the main line and WS is a side track. A turnout is sometimes called a *switch*, but, properly speaking, the switch is only one part of the turnout The principal parts of a turnout are: (*a*) a movable *switch* $ABCD$ to guide the wheels to one track or the other, (*b*) a *frog* $a\,b$ at the intersection of the rails of the two tracks to provide for the passage of the wheel flanges, and (*c*) the *lead rails* connecting the switch with the frog

2. Types of Switches.—There are two general types of track switches, namely, the *split*, or *point*, *switch* and the *stub switch*. The point switch, $ABCD$ in Fig 1, is used almost exclusively; the stub switch, Fig 2, has several important disadvantages and is, therefore, employed only to a limited extent for unimportant sidings and industrial tracks The explanations in this Section refer chiefly to the point switch

3. Parts of Switch.—The main parts of a switch are two switch rails AB and DC, Figs 1 and 2; in a point switch, these

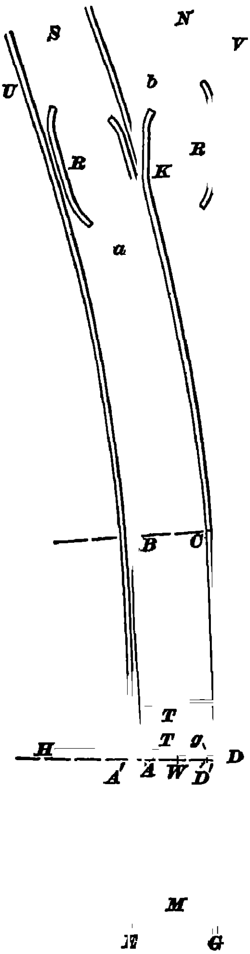


Fig 1

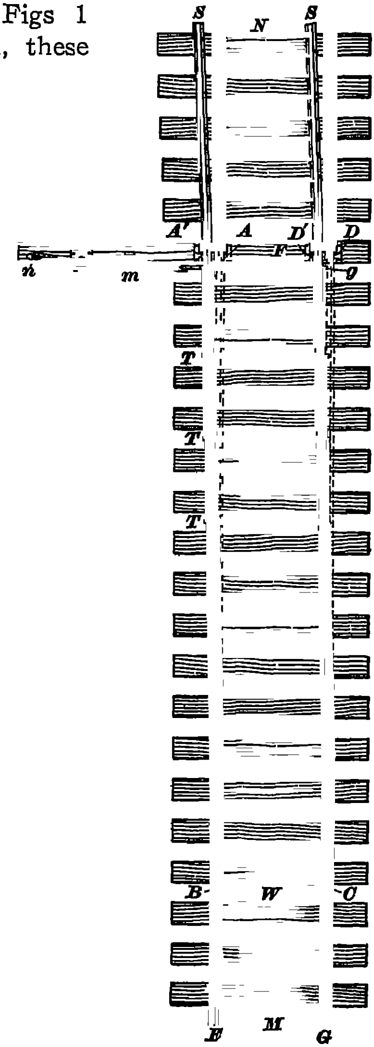


Fig 2

rails are sometimes called *point rails*. The heel of switch is at the fixed ends of the switch rails, B and C. The toe of switch is at the movable ends of the switch rails, A and

D. The switch rails are connected at the toe by means of tie-rods T so as to move simultaneously in a lateral direction The end tie-rod g is called the *head-rod* or *No 1 rod,* it extends outside the rails and is connected to a device for moving the switch

The point of switch is the point where the center line of the turnout meets the center line of the main track, as W in Figs. 1 and 2 Thus, the point of switch is at the heel in a stub switch and at the toe in a split switch.

The distance AA' or DD' through which the switch rails move at the head-rod is called the *throw of switch,* the American Railway Engineering Association recommends a throw of 5 inches The distance from the main-track rail to the switch rail at the heel of switch is called the *heel distance* It is measured between the gauge sides of the rails and is usually from $5\frac{1}{2}$ to $6\frac{1}{2}$ inches to allow room for spiking the rails

The switch angle is the angle between the main-track rail and the switch rail, as VDC in Fig 1 and DCD' in Fig 2.

4. Facing and Trailing Switches.—When a train is running in such a direction that it passes the switch before reaching the frog, as in running from M to N, Fig 1, it is said to *face* the switch, and the switch is called a *facing switch* A train running in the opposite direction, from N to M, is said to *trail* the switch, and the switch is then a *trailing switch* On double-track lines, practically all switches for sidings can be arranged as trailing switches, then trains to be sidetracked will run in the direction opposite that usually proper on the main track and thus back into the siding. This avoids the possible chance of diverting a train from its course by a facing switch in the wrong position.

5. Switch Construction.—The usual construction of a point switch, together with the operating mechanism, is shown in Fig 3. The point rails CC' and DD' are usually straight and from 12 to 30 feet long, depending on the angle of turnout The head of each is planed away at the toe to form a tapering end or tongue so as to fit closely against one of the fixed rails, or *stock rails*, AA' or BB', for a length of 6 to 12

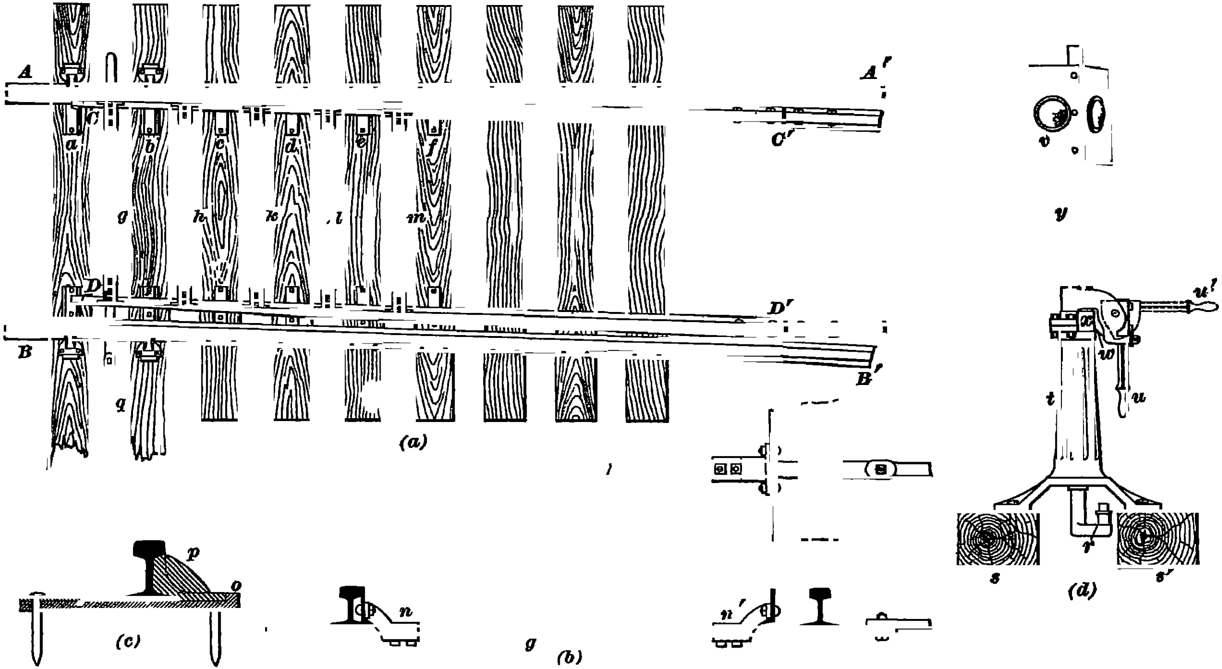


Fig 3

feet The switch rails are not planed to a very fine edge, but are usually $\frac{1}{4}$ inch thick at the movable ends It is not necessary to consider the theoretical point where the direction of the switch rail intersects the stock rail, because the length of the switch rail is measured to the actual point, and the actual point is placed opposite the point of switch

Near the ends of the switch rails their outer flanges are cut away so that the tongue will rest on the flange of the stock rail, as shown in Fig 4 At the extreme points the tops of the heads of the switch rails are also planed away on an incline so that the wheel treads *A B* will not come in contact with the rails until the flanges reach a thicker and stronger part that is better able to stand the blows and pounding of the wheels The thin point or tongue may be strengthened by a reinforcing bar or an angle riveted along the web

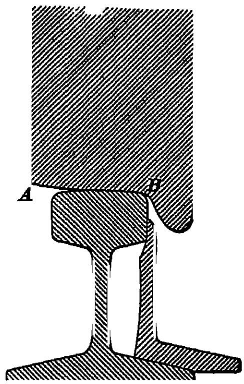


FIG 4

As a protection to the point of the switch rail, the turnout stock rail *E U*, Fig 1, is given a slight outward bend or knuckle just in advance of the point and then bent outwards to conform to the turnout curve This knuckle is formed with a rail bender Its distance ahead of the point is about as given in Table I

TABLE I

LOCATION OF KNUCKLE

Length of switch rail, feet	11	15	$16\frac{1}{2}$	24	30
Distance from point to knuckle, inches	7	8	9	13	$16\frac{1}{4}$

6. Switch Operation.—In Fig 1 the switch is shown in position for the turnout, so that a train moving from *M* will travel toward *S* Thus, the flanges of wheels on the right-

hand rail will be guided away from the main line by the switch rail DC, while the flanges of the wheels on the left-hand rail will pass through the open space between the switch rail AB and the turnout rail EU

When the switch is set so that a train moving from M will be guided along the main track to N, the switch rail BA will be in the position BA' with the tapered end against the stock rail EU, and the switch rail CD will be in the position CD' so as to leave an opening or flangeway for the wheel flanges

The operation of moving the switch from one position to the other is called *throwing the switch.* Switches may be thrown mechanically by suitable connections from a switch tower or by hand by means of a device called a *switchstand* placed at the turnout The splice joints at B and C, Fig 1, are sufficiently flexible to allow the switch rails AB and DC to move with respect to the lead rails BK and CK

A long tie called a *headblock* is placed at the point of switch and projects far enough to support the switchstand and thus maintain it in proper position relative to the switch Sometimes the headblock consists of two long ties placed close together to give a more substantial support to the switch points and the switchstand, and also to protect the head-rod which is placed between the two ties as shown in Fig 3 (a).

For easy and proper movement, the switch must be in good condition, but the passage of traffic tends to disturb the track and loosen the parts It is important, therefore, to maintain the switch in good line and level and to keep all bolts tight and all movable parts properly adjusted.

7. Slide Plates.—To protect the ties from wear by the moving switch rails and to give these rails a firm bearing surface on which they will slide easily, steel slide plates, a to f in Fig 3 (a), are placed under the stock rails and switch rails These plates are spiked to the ties and are kept well greased They may be shaped to form lugs fitting against the base of the stock rail, or they may be fitted with rail braces supporting the outer side of the stock rail, as at op in (c).

8. Switchstands.—A common form of a switchstand is shown in Fig 3 (*d*) The stand *t* is mounted on the ends of two long ties *s* and *s′* forming the headblock, and carries a vertical shaft *y*, having at its upper end a target *v* and at its lower end a crank *r* to which the switch connecting-rod *q*, view (*a*), is attached The target *v* consists of two rectangular pieces of sheet iron fastened to the shaft at right angles to each other The two pieces are painted in different colors and the position of the target indicates whether the switch is set for the main track or for the turnout. Various forms and colors are used for targets A handle *u* is pivoted to a casting *w* on the shaft In its vertical position, this shaft is inoperative and may be locked to a lug on the stand. To

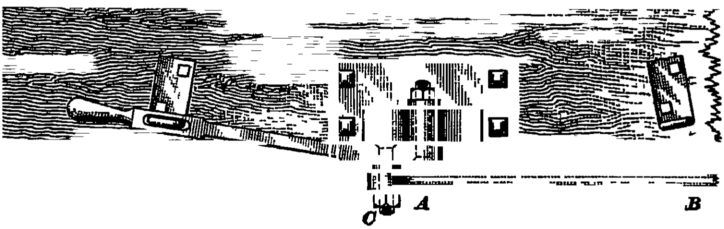


FIG 5

throw the switch, the handle is first raised to the horizontal position *u′*, this brings its inner end into engagement with a lug *x*, so that when the handle is moved in a horizontal plane the shaft is turned and the positions of the target *v* and the crank *r* are changed At night a lamp is placed on the top of the shaft

Switchstands of this type are used both for main-track and yard switches, but sometimes with a taller shaft for the target Short, or dwarf, switchstands are used at crossovers and yards A simple form of a switchstand, known as the *ground lever*, or *drop lever, switchstand*, for use on unimportant tracks, is shown in Fig 5 The switch connecting-rod *AB* is attached to a pin *C* on a hand lever pivoted in a casting on the headblock. When the lever is turned vertically through a half circle so that its slotted handle fits over the staple on the plate at the

right, the rod AB is forced to the right, moving the switch rails correspondingly Such a switchstand is shown in position in Fig 2 where n is the lever, m is the connecting-rod, g is the head-rod, and F is the headblock In a better design, shown in Fig 6, the lever moves parallel with the rails

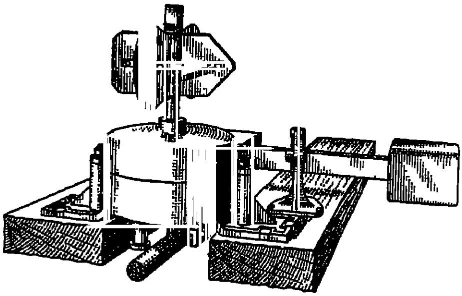


Fig 6

9. Safety, or Automatic, Switches and Switchstands.—It is sometimes desirable to arrange a point switch so that trains may trail through it when misplaced without breaking it This may be provided for by placing a spring in the head-rod con-

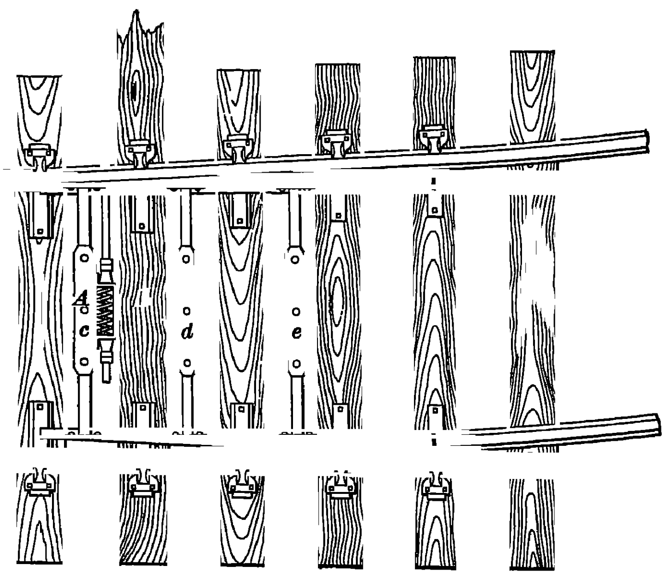


Fig. 7

nections, as at A, Fig. 7. The spring is stiff enough to throw the switch in ordinary operation, but allows the connection to

be moved by the severe force applied by the wheels of trains This device is known as a *safety switch* The spring returns the switch rails to position after each wheel has trailed through the switch and, therefore, the following wheel must force the switch rail open again After the train has passed the switch is in the same position as before. Automatic switchstands have springs between the shaft and the connecting-rod, and may be so arranged that when the wheels force the switch rails over, the springs will throw the switch to the open position, the target and lamp also indicating the new position In this case all the following wheels have an unobstructed passage through the switch, instead of having to force the switch rail open After the train has passed, the switch is in the opposite position to what it was before

10. Stub Switch.—The stub switch, shown in Fig 2, is now used little, especially in important tracks, its limited use being confined mainly to the cheaper kind of work in yard and industrial tracks No tapered switch rails are used, but at the turnout the two stock rails BA' and CD' are left loose on slide plates so that their ends may be shifted laterally to line up with either the main track or the turnout rails.

At the heel the switch rails are spliced to the main-track rails E and G Their toes rest on plates, called *head-chairs*, which are spiked to the headblock F, and are formed with sockets to receive the ends of the bases of the main-track rails at A and D and the turnout rails at A' and D' In Fig 2, the switch is shown in position for the turnout WS. To set it for the main track MN the rails are thrown to the right to the positions indicated by the dotted lines The rails are connected by tie-rods T, so that they move as a unit when the switch is thrown

11. Comparison of Switches.—The point switch has great advantages over the stub switch in stability and safety When a point switch is set for either track, the guiding rails are held firmly against the stock rails and form an unbroken

path in the desired direction. Thus, since there is little vibration and no slackness or lost motion, trains may pass at full speed in safety For the turnout track, the speed will be limited to that which is safe for the turnout curve A misplaced point switch does not lead to derailment If a train trails through a misplaced switch the wheel flanges will usually force the switch rail open, while, if it runs through a misplaced facing switch, it will only be diverted to the wrong track

A stub switch is necessarily much less finely adjusted than a point switch A fairly wide gap must be left between the ends of the fixed and switch rails to allow for variations in temperature, and, even if the two rails are in good line, there will be a severe shock as each wheel crosses this gap. As a result, there is much vibration and noise, the cars are jolted, the switch parts are loosened, and the rail ends are battered so that the rails must be cut and refitted frequently As the switch rails are less securely held than in the point switch, the stub switch is less safe for high-speed trains The most serious objection, however, is the danger of derailment by a misplaced switch It will be seen that when a main-line train comes from *N*, Fig 2, the wheels will run off the ends of the rails at *A* and *D*. Or with the switch set for the main track, a train from the siding would be derailed

12. Tie-Rods and Head-Rods.—Five switch rods or tie-rods *g* to *m* are shown in Fig 3 (*a*), but it is more general practice to use only one or two rods in addition to the head-rod *g*. As shown in (*b*), the head-rod *g* is attached to the switch rails by means of sockets *n* and *n'* so shaped that the rod can pass under the rails for attachment to the extension rod or connecting-rod *q*, view (*a*) This rod connects the switch with the crank *r* on the shaft of the switchstand shown in (*d*) Common forms of tie-rods are shown in Fig 8, the lugs *m* and *n* are about 5 inches long and are bolted firmly to the webs of the switch rails The tie-rod shown in (*a*) is hinged, so as to cause it to operate more easily, an unhinged form is shown in (*b*) The tie-rod in (*c*) is shown in position in the track at *d* and *e*, Fig 7. This form is bent downwards nearly to a level

with the top of the tie, where it is less exposed to injury from derailed cars or from broken parts of the cars, such as brake rods or beams, which, dragging on the ties, frequently catch in switch rods and do much harm The form shown in Fig 8 (*d*) is used only with stub switches, the tie-rods are slipped over the ends of the rails, and fastened into place by hammering down the free ends of the prongs on the rail flanges.

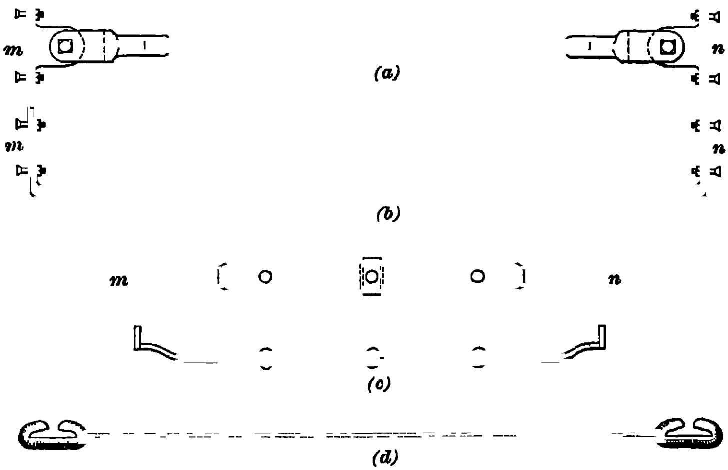


FIG 8

When the form in (*a*) or (*b*) is used for the tie-rods, the head-rod may be of the form shown in Fig 3 (*b*); when the form in Fig. 8 (*c*) is used for the tie-rods, the head-rod is as shown at *c* in Fig 7, but the spring is used only for automatic switches. A stub-switch head-rod is shown in position at *g*, Fig. 2.

13. Lead Rails.—It will be observed that the right-hand stock rail, *G V*, Fig. 1, continues unbroken along the main track, while the left-hand stock rail *E U* continues unbroken along the side track or turnout The lead rails *KB* and *KC* connect the frog *a b* with the switch rails and complete the two continuous tracks, they are known as the *straight lead rail* and *curved lead rail*, respectively. Obviously, the curved lead rail must be slightly longer than the straight rail. Ordi-

narily, the rails must be cut to different lengths, but in spring-rail frogs, the difference in length may be made up in the frog The difference in length will usually be from 1 to 4½ inches

FROGS

14. Frog Construction.—At the intersection of the rails in a turnout, as at K, Fig 1, it is necessary to provide gaps or openings to permit the wheel flanges to pass through or across either line of rails, and at the same time to give as nearly as possible a continuous bearing for the treads of the wheels These requirements are effected by a combination of rails and castings built up to form a *frog*, the main elements of which are shown in Fig 9 To guide the wheels and hold them in

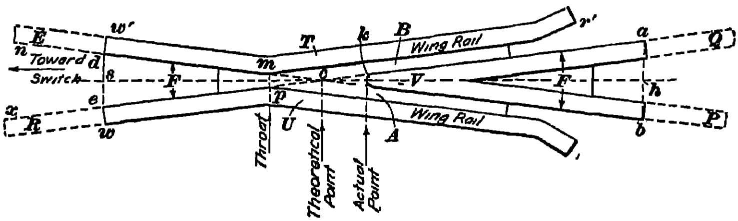


FIG 9

line so that their flanges will pass through the proper opening of the frog, guard-rails R, Fig 1, are provided opposite the frog Thus with a car moving on the diverging branch or turnout to S, the left guard-rail will hold the flange of each left-hand wheel close against the rail EU and insure that the flange on the opposite wheel will pass in the groove to the left of the frog point On the other hand, if the switch is set for the main track, the right guard-rail will hold the flange of each right-hand wheel close against the rail GV, so that the flange on the opposite wheel will pass in the groove to the right of the frog point.

In Fig 9, RQ is the line of the inner rail of the main track and EP is the line of the outer rail of the side track or turnout The two lead rails E and R stop at the frog, their ends being bent out to form flaring wings on either side of the pointed piece V that is connected to the ends of the two track rails P and Q.

With a main-track train coming from the switch, at the left, the wheel flanges ride against the gauge side of the rail head from x to p, the tread of the wheel rolling on top of the rail From p the flange is forced to pass through the groove or flangeway B along the line pa, being prevented from entering the channel A or striking the point V by the guard-rail which holds the wheel on the other end of the axle against the opposite rail The tread rolls across the rail head at U and across the groove A to the point V The wheel then continues along to the main rail Q, with its flange riding along the side a of the rail head

If a train is entering the turnout, the flanges of the outer wheels ride against the gauge side of the rail head from n to m, passing through the groove A, while the treads of the wheels pass across the rail head at T and the other groove B to the point V and continue on to P Each wheel is kept in line as it passes through the frog by means of the wheel on the other end of the axle, which is held against the opposite rail by the guard-rail.

15. Parts of Frog.—In Fig 9, the wedge-shaped or triangular center portion of the frog at V is known as the *tongue*, or *frog point* Its blunt end k is called the *actual point of frog*, while the intersection of the gauge lines ac and bc at c is the *theoretical point of frog* The bent ends wr and $w'r'$ of the lead rails are the *wing rails* The *throat* is the narrowest part of the flangeway or groove at mp, it is usually $1\frac{3}{4}$ or $1\frac{7}{8}$ inches wide The *toe of frog* is the end ww' nearer the switch, and the opposite end ab is the *heel of frog*

16. Types of Rigid Frogs.—In rigid frogs there are no movable parts As a rule, the frog is built up of rails of the same section and weight as those of the main track, planed and bent to shape and bolted or clamped together The rails forming the point are riveted Fillers in the throat and flangeways fit between the webs of the rails and give the proper width of groove A filler block is also fitted between the rails that form the frog point As the point and throat are subjected to severe wear, they are often made of hard

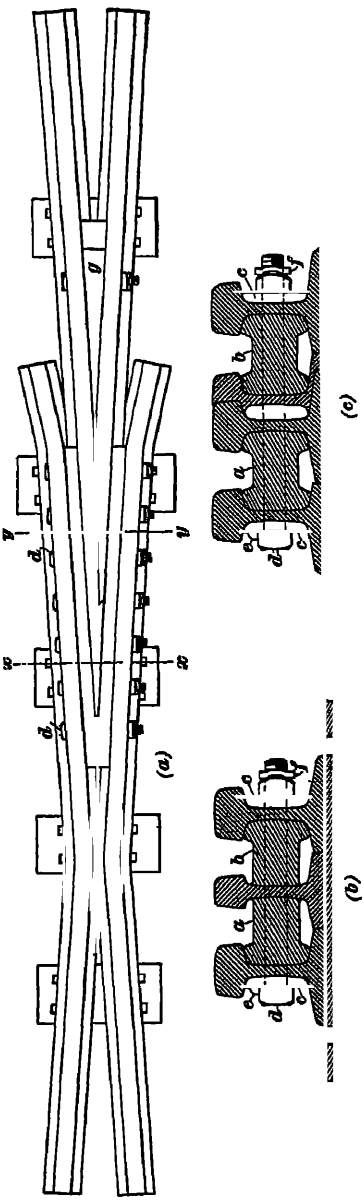


Fig 10

manganese-steel castings, the rails forming the remainder of the frog being shaped to fit the castings, and the parts are securely bolted together

Frogs which are put together with bolts through the rail webs and the fillers, as shown in Fig 10, are the most widely used In (*a*) is a plan view, and in (*b*) and (*c*) are the sections at *x x* and *y y*, respectively The fillers *a* and *b* and the washers *c* are shaped to fit against the rails, and the parts are held together by means of the bolts *d* Nut-locks *e* and *f* are used to prevent the bolts from becoming loose Bolted frogs may be strengthened by base plates riveted under the rails

Clamped or keyed frogs, Fig 11, are also used extensively In this type of frogs the pieces of rails *a* and *b* in (*a*), forming the tongue, are dovetailed together and secured by heavy rivets To retain the full strength and durability of the steel, the parts except the wings are fitted without heating, the wings, however, are bent at a very

low heat The parts are bound by heavy wrought-iron clamps *c* and *d*, a cross-section through the first clamp is shown in (*b*), and one through the second clamp, in (*c*) Each clamp is bent at one end to fit the brace-block *k* on the outside of the rail, and at the other end to fit the beveled key *e*, which is driven into the space between the end of the clamp and the smaller brace-block *l* to tighten the clamp The keys lie on the flange of the rail, which prevents them from dropping down in case they loosen The flangeway between the frog point and the wing rails is maintained by iron throat-pieces *g*, *h* that fit the rails per-

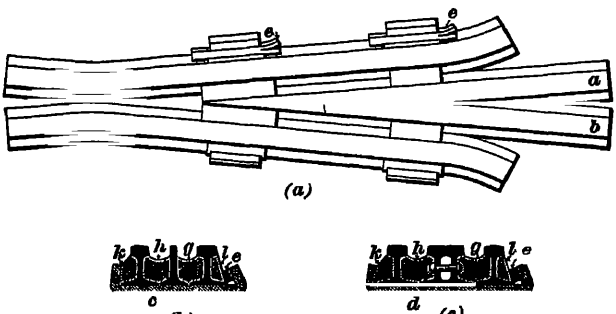


FIG 11

fectly and, extending to the point, thoroughly brace it against lateral stresses After the keys are driven to the extent necessary to bind the parts solidly together, the split ends are spread to prevent the keys from working out

A stiffer form of a clamp is a thin deep plate notched out for the rails and placed on edge in a vertical plane instead of laid flat as in Fig 11 For light track, a *plate frog* having the rails riveted directly to a base plate the full length and width of the frog is sometimes used Flangeway fillers are dispensed with in the plate frog

17. Spring-Rail Frogs.—At many turnouts one track is used much more than the other or carries faster trains than the other, and, therefore, it is desirable to reduce the shock and wear on one side of the frog In such cases a spring-rail frog is used, in which the main-track rail *pr*, Fig 9, is hinged between *w* and *p* and is held normally in contact with the side

cb of the frog point by means of a spring The wheels of main-line trains have then a continuous bearing, with no gap or flangeway to be crossed between the spring rail and the frog point. This causes the trains to ride more smoothly and relieves wear of the track and wheels. When a train on the turnout reaches the frog, the wheel flanges force out the wing rail *pr* and thus open the flangeway *A*.

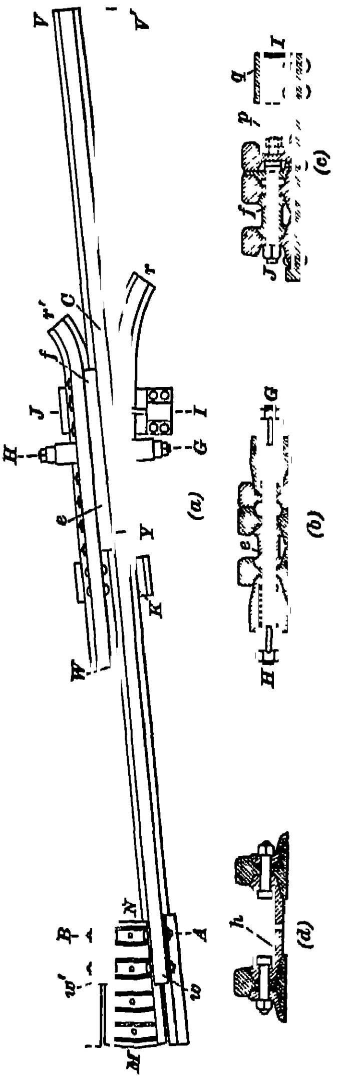


FIG 12

In the spring-rail frog shown in Fig. 12 (*a*), the frog point is at *Y* The fixed wing rail *w′ r′* has the usual flangeway filler *cf*; sections through *GH* and *IJ* are shown in (*b*) and (*c*). On the opposite side is the spring rail or movable wing rail *wr*, which is normally held against the frog point *Y* by the two springs and the through bolt *GH* as shown in (*b*) When a train comes from *V′*, the flange of each wheel will wedge between *C* and *r*, forcing the spring rail outwards so that the wheel flange can pass on to *W*, the throat of the frog As soon as the wheel has passed the frog point, the springs return the wing rail into position With a train running from *w′* to *V′*, each wheel flange will strike the wing rail at *W* and force it open so that the flange can pass on the right-hand side of the frog

point The flange cannot travel from w' to V, since the wheel on the other end of the axle is held over toward the right by the guard-rail, as explained in the discussion on rigid frogs

At the toe of the frog, the ends of the frog rails and the lead rails are bolted to the anchor block MN in (*a*) as shown in (*d*), which is a section through $A B$ The anchor block, which is the **U**-shaped frame h, is spiked to the ties to hold the frog in place Vertical movement or play of the spring rail is prevented by the lug p in (*c*) that is riveted to the rail web and slides in the collar or socket q on the base plate A stop or lug, K in (*a*), limits the movement of the spring rail so that the width of opening or flangeway cannot exceed $1\frac{7}{8}$ inches at the frog point

18. Frog Guard-Rails.—As already explained, guard-rails are placed close to the track rails opposite the frog in order to hold the wheels in line to pass through the frog properly The length is usually 10 or 15 feet, the rails being bent out at the ends to give an easy entrance to the flangeway It is well to have the guard-rail resting on tie-plates that also carry the track rail, and to bolt the two rails together with the necessary spacing blocks between the webs in order to insure a permanent and uniform width of flangeway of $1\frac{7}{8}$ inches. The outer flange of the guard-rail must be cut away so that the proper flangeway may be secured

19. Continuous-Rail Frogs.—Since the frog is a weak point in the track and a cause of wear and expense to track and rolling stock, different forms of construction have been devised to provide continuous or unbroken rails in the main track at turnouts where the branch track is relatively less important In general, this is done by raising the curved or turnout lead-rail CK, Fig 1, beyond the heel of switch at such an inclination as to carry the wheels high enough to allow the flanges to pass over the main rail The turnout rail beyond the frog is raised to the same height The gap left in the turnout rail may be closed by a hinged rail or casting, which stands clear of the main rail when the switch is set for the main track. This device is operated in connec-

tion with the switch, so that when the switch is thrown for the turnout the hinged rail is swung across the main rail to provide a continuous bearing for wheels on the turnout

20. Easer Rails.—The treads of the wheels wear down rapidly near the flanges and, as a result, the outer edge of the tread on an old wheel forms a projection similar to a flange which is termed a *false flange* When the wheel crosses a frog this projection strikes the wing rail, as at T or U in Fig 9, and jars the rail and the rolling stock In order to carry the projection across the wing rail and thus reduce the battering, a short rail called an *easer rail,* is bolted outside of, and close against, the wing rail.

21. Heel Blocks.—The false flange on the edge of a worn wheel also causes trouble when it drops between the rails forming the tongue of the frog and tends to wedge them apart This difficulty is relieved by bolting a heel block g, Fig 10, between the tongue rails The surface of this block slopes downwards toward the heel of the frog so that the wheels are raised or lowered gradually.

DIMENSIONS OF TURNOUTS

FROG DIMENSIONS

22. Frog Angle and Frog Number.—The angle $a c b$, Fig 9, between the gauge lines of the tongue of the frog is called the *frog angle* This is also equal to the angle $d c e$ between the gauge lines produced beyond c. The frog angle is represented by F.

Since $x c a$ is the gauge line of the inner rail of the main track, and $n c b$ is the gauge line of the outer rail of the side track, the frog angle is also equal to the angle between the two tracks

The distance $a b$ between the gauge lines at the end of the tongue is called the *heel width* or *spread at heel,* the distance $d e$ is called the *toe width* or *spread at toe* If $s c h$ is the bisector of the angle F, the distance $c h$ is called the *length of frog.*

The ratio of the length to the heel width is called the *frog number*, and is usually denoted by N, that is,

$$N = c\,h \div a\,b$$

The relation between N and F is found as follows:

$$N = \frac{c\,h}{a\,b} = \tfrac{1}{2}\frac{c\,h}{a\,h}$$

But in the triangle $a\,c\,h$,

$$\cot a\,c\,h = \cot \tfrac{1}{2} F = \frac{c\,h}{a\,h}$$

Therefore, if this value is substituted in the expression for N,

$$N = \tfrac{1}{2} \cot \tfrac{1}{2} F \qquad (1)$$

Then,

$$\cot \tfrac{1}{2} F = 2\,N \qquad (2)$$

Frogs are designated by their numbers, thus, a No 8 frog is one in which $N = 8$

Although formulas 1 and 2 are easily applied, it is convenient to make use of a table such as Table II, that gives the frog angle

TABLE II

FROG NUMBERS WITH CORRESPONDING FROG ANGLES AND THEIR TRIGONOMETRIC FUNCTIONS

Frog Number N	Frog Angle F Deg	Min	Sec	Nat sin F	Nat cos F	Log sin F	Log cos F	Log cot F
4	14	15	00	.24615	96923	9 39120	9 98642	.59522
5	11	25	16	.19802	98020	9 29670	9 99131	69461
6	9	31	38	.16552	.98621	9 21884	9 99397	77513
7	8	10	16	.14213	98985	9 15268	9 99557	84288
8	7	9	10	12452	99222	9 09522	9 99660	90138
9	6	21	35	11077	99385	9 04442	9 99732	95289
9½	6	1	32	10497	99448	9 02107	9 99759	97652
10	5	43	29	09975	99501	8 99891	9 99783	99892
11	5	12	18	09072	99588	8 95770	9 99820	1 04050
12	4	46	19	08319	99653	8 92007	9 99849	1 07842
15	3	49	6	06659	99778	8 82343	9 99904	1 17561
16	3	34	47	06244	99804	8 79544	9 99915	1 20371
18	3	10	56	05551	99846	8 74438	9 99933	1 25494
20	2	51	51	04997	99875	8 69869	9 99946	1 30076
24	2	23	13	04165	99913	8 61959	9 99962	1 38003

corresponding to each frog number, and also the trigonometric functions of this angle.

EXAMPLE 1.—Find the frog angle of a No 7 frog.

SOLUTION.—In this case $N=7$, and from formula **2**,

$$\cot \tfrac{1}{2} F=2\times 7=14$$

Therefore, $\tfrac{1}{2} F=4° 5' 8''$, and $F=8° 10' 16''$. Ans

The same result can be taken directly from Table II

EXAMPLE 2.—If the frog angle is 7°, what is the frog number?

SOLUTION —From formula **1**,

$$N=\tfrac{1}{2}\cot\frac{7°}{2}=\tfrac{1}{2}\cot 3° 30'=8\ 2$$

However, standard frogs are made in whole numbers and, unless a special frog is to be made to order, a No 8 frog would be used

This problem can be solved directly by Table II. In the second column it is found that 7° lies between 6° 21′ 35″ and 7° 9′ 10″, the angles corresponding to a No 9 and a No 8 frog, respectively However, as a standard frog is to be used, it is not necessary to interpolate in the table The standard frog angle nearest to 7° is 7° 9′ 10″, this corresponds to a No 8 frog. Ans.

23. Finding Number of Frog by Measurement.—The number of a frog may be found by measurement, as follows. In Fig. 9,

$$c\,h=a\,h\cot\tfrac{1}{2}F$$
$$c\,s=d\,s\cot\tfrac{1}{2}F$$

Therefore, by addition,

$$c\,h+c\,s=(a\,h+d\,s)\cot\tfrac{1}{2}F$$
$$=\left(\frac{a\,b}{2}+\frac{d\,e}{2}\right)\cot\tfrac{1}{2}F$$

But $ch+cs=sh$; and, from the preceding article, $\tfrac{1}{2}\cot\tfrac{1}{2}F=N$. Therefore,

$$s\,h(=a\,b+d\,e)N$$

whence

$$N=\frac{s\,h}{a\,b+d\,e}$$

If the whole distance $s\,h$ and the widths $a\,b$ and $d\,e$ are measured on the frog and their values substituted in this formula, the result will be the frog number By this method, N may be found much more accurately than by attempting to measure

ch and ah on the frog, because the theoretical point c cannot be accurately found in practice

EXAMPLE —The distance sh was measured on a frog and found to be 17 feet 6 inches The heel width ab was 12½ inches, and the toe width de was 6½ inches What was the frog number?

SOLUTION.—When the values are substituted in the formula,

$$N = \frac{17 \text{ ft } 6 \text{ in}}{12.5 \text{ in} + 6.5 \text{ in}} = \frac{210 \text{ in.}}{19 \text{ in.}} = 11. \quad \text{Ans.}$$

24. Selection of Frog Numbers.—Although there is a great range in frog numbers, it is best to use as few numbers as possible for simplicity and for economy in renewals Numbers 8, 10, and 12 are used largely in main-track turnouts, number 16 is used if trains move at high speed, as where switch and signal interlocking plants are installed. Numbers 18

TABLE III

LENGTHS OF SWITCH RAILS

Frog Number	Length of Switch Rail, in Feet
4 to 7 or 8	11 or 15
8 to 10	15 or 16½
12 to 16	22 or 24
20 to 24	30 or 33

and 20, or even 24, are used at the ends of double tracks or where trains pass from one track to a nearby parallel track at high speed Numbers 6, 7, and 8 are used largely in yards and industrial tracks. Numbers less than 7 should be used only where necessary

The length of the switch rail varies with the frog number about as given in Table III

EXAMPLE FOR PRACTICE

Solve the following problems both by the formulas and by the table.

(a) If $N=6$, find F
(b) If $N=9$, find F
(c) If $F=5° 44'$, find N
(d) If $F=5°$, find N

Ans $\begin{cases} (a)\ 9° 31' 38'' \\ (b)\ 6° 21' 35'' \\ (c)\ 10 \\ (d)\ 11 \end{cases}$

TABLES FOR TURNOUTS

25. Lead.—The *lead* is the distance measured along the center line of the main track from the actual point of switch to the point of frog, sometimes the theoretical point of frog is considered and sometimes the actual point is used The length of the straight lead rail from the heel of switch to the toe of frog is called the *closure of straight rail*, and the length of arc of the curved lead rail from the heel of switch to the toe of frog is the *closure of curved rail.*

Theoretically, the curved lead rail should be bent to a simple circular curve, to which the switch rail is tangent at the heel of switch and the frog rail is tangent at the toe of frog For such a condition the lead is called the *theoretical lead* However, if the theoretical lead were used, the closure of both straight and curved rails would be a number of feet and a fraction or decimal of a foot In order to make one of the closure rails full feet without a fraction, and thus avoid cutting one of the rails, the theoretical lead is modified If it is desired to increase the lead, a short tangent is introduced at the heel of switch, if it is desired to decrease the lead, a short tangent is placed at the toe of the frog For the modified condition the lead is called the *practical lead* The curved lead rail is bent to a simple circular curve, but its radius is slightly different from that for the theoretical lead

26. Table for Turnouts With Split Switches.—Computing the dimensions of the several elements of a turnout involves such complicated and tedious work that it is usual to obtain these dimensions from prepared tables Theoretical and practical leads and other dimensions for split-switch turnouts with frog numbers from 4 to 24 are given in Table IV These values, which are for track with a standard gauge of 4 feet $8\frac{1}{2}$ inches, have been adopted by the American Railway Engineering Association

In columns 1 to 7 are given the dimensions of the frogs corresponding to the various frog numbers The thickness of the actual frog point k, Fig 9, is taken as $\frac{1}{2}$ inch in all cases The values in columns 8 to 14 are for the theoretical lead

The thickness at the point of switch and the heel distance are assumed to be ¼ inch and 6¼ inches, respectively For these conditions, the closures of both straight and curved rails contain decimals of a foot The distance in column 12 from the point of switch rail to the theoretical point of frog is the theoretical lead

In columns 15 and 16 are given the radius and the degree of curve for the practical lead, while the values in columns 17 to 22 are for use in bending the curved lead rail to the desired curvature For instance, for a No 8 frog, one quarter point of the curved lead rail is placed by measuring 28 37 feet from the point of switch, and 1 02 feet from the gauge side of the stock rail, the center point is located by measuring 39 91 feet from the point of switch and 1 78 feet from the stock rail; and the other quarter point is found by measuring 51 45 feet from the point of switch and 2 91 feet from the stock rail

The other values required to lay out a turnout are also given in the table In columns 23 and 24 are found the tangent distances, introduced at the heel of switch or at the toe of frog, to give the practical leads The practical leads to the theoretical point of frog and to the actual point of frog are in columns 25 and 26, respectively The difference between the theoretical lead and the practical lead can be seen by comparing columns 12 and 25 When the practical lead is greater than the theoretical lead, the tangent distance T_s is introduced at the heel of switch, on the other hand, when the practical lead is less than the theoretical lead, the tangent distance T_f is introduced at the toe of frog Columns 27 and 28 give the lengths of lead rails to be used. Thus, for a No 8 frog, the straight lead rail is composed of one rail 30 feet long and one rail 16 40 feet long, and the curved lead rail consists of one rail 30 feet long and one rail 16 60 feet long It is desirable to have the rails of approximately equal length, and rails shorter than 10 feet should not be used.

EXAMPLE —Find the dimensions of a split-switch turnout with a No 12 frog

SOLUTION —From column 25 of Table IV, the length of lead from the point of switch to the theoretical point of frog is found to be 100 30 ft.

TABLE IV

DIMENSIONS OF TURNOUTS WITH SPLIT SWITCHES

Frog Number N	Frog Angle F	Length Theoretical Point to Toe W	Length Theoretical Point to Heel K	Total Length of Frog	Spread at Toe	Spread at Heel	Length of Switch Rail S	Switch Angle A	Radius of Center Line R	Degree of Lead Curve D	Distance From Point of Switch Rail to Theoretical Point of Frog	Closure for Straight Rail	Closure for Curved Rail
	Properties of Frogs Thickness of all Frog Points ½ Inch					Properties of Switches for all Switches Thickness of Point ¼ Inch Heel Distance 6¼ Inches			Theoretical Leads				
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Deg Min Sec.	Ft In	Ft In	Ft In.	Feet	Feet	Ft. In	Deg Min Sec	Feet	Deg Min Sec.	Feet	Feet	Feet
4	14 15 00	3 2	5 4	8 6	79	1 32	11 0	2 36 19	112 26	52 53 56	37 05	22 88	23 29
5	11 25 16	3 7	6 5	10 0	.71	1 28	11 0	2 36 19	183 22	31 40 24	42 77	28 19	28 55
6	9 31 38	4 0	7 0	11 0	66	1 16	11 0	2 36 19	273 95	21 01 58	48 11	33 11	33 38
7	8 10 16	4 5	8 1	12 6	63	1 15	16 6	1 44 11	364 88	15 47 19	61 94	41 02	41 24
8	7 09 10	4 9	8 9	13 6	59	1 09	16 6	1 44 11	488 71	11 44 40	67 47	46 22	46 42
9	6 21 35	6 0	10 0	16 0	67	1 11	16 6	1 44 11	616 27	9 18 27	72 24	49 74	49 92
9½	6 01 32	6 0	10 0	16 0	.63	1 05	16 6	1 44 11	699 97	8 11 33	74 90	52 40	52 58
10	5 43 29	6 0	10 6	16 6	60	1 05	16 6	1 44 11	790 25	7 15 18	77 51	55 01	55 17
11	5 12 18	6 0	11 6	17 6	54	1 05	22 0	1 18 8	940 21	6 05 48	92 06	64 06	64 20
12	4 46 19	6 5	12 1	18 6	53	1 01	22 0	1 18 8	1,136 34	5 02 38	97 25	68 83	68 96
15	3 49 06	7 8	14 10	22 6	51	99	33 0	0 52 5	1,744 45	3 17 06	130 50	89 83	89 94
16	3 34 47	8 0	16 0	24 0	50	1 00	33 0	0 52 5	2,005 98	2 51 24	135 95	94 95	95 05
18	3 10 56	8 10	17 8	26 6	49	98	33 0	0 52 5	2,587 66	2 12 52	146 38	104 54	104 61
20	2 51 51	9 8	19 4	29 0	48	97	33 0	0 52 5	3,262 98	1 45 22	156 35	113 68	113 76
24	2 23 13	11 4	23 2	34 6	47	97	33 0	0 52 5	4,932 77	1 09 42	175 09	130 66	130 77

TABLE IV—(*Continued*)

Frog Number N	Radius of Center Line R	Degree of Lead Curve on Center Line D	Rectangular Coordinates to the Quarter and Center Points on Gauge Side of Curved Rail, Referred to Point of Switch Rail as Origin — X	X_1	X_2	Y	Y_1	Y_2	Tangent Adjacent to Switch Rail T_s	Tangent Adjacent to Toe of Frog T_f	Lead Actual Point of Switch Rail to Theoretical Point of Frog L_1	Lead Actual Point of Switch Rail to Actual Point of Frog L	Closure for Straight Rail		Closure for Curved Rail	
1	15	16	17	18	19	20	21	22	23	24	25	26	27		28	
	Feet	Deg M'n S'c	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Number and Length of Rails		Number and Length of Rails	
4	110 69	53 42 24	17.74	23.44	29.75	97	1 67	2 79	1 03	00	37 77	37 94	1–23 60		1–24	
5	174 34	33 19 57	17 78	24 54	31 27	95	1 61	2 62	.00	82	42 26	42 47	1–27 68		1–28	
6	265 39	21 43 04	19 07	27.13	35 15	1 01	1 74	2 72	00	.66	47.73	47 98	1–32 73		1–33	
7	362 08	15 52 29	26 72	36 93	47.11	.97	1 71	2 74	00	19	61 81	62 10	1–13 89	1–27	1–14 11	1–27
8	487 48	11 46 27	28 37	39 91	51.45	1 02	1 78	2 91	30	00	67.65	67 98	1–16 40	1–30	1–16 60	1–30
9	605 18	9 28 42	28 75	40 98	53 19	1 02	1.76	2 75	00	57	71 91	72 28	1–16 41	1–33	1–16 59	1–33
9½	695 45	8 14 45	30 31	43 35	56 37	1 06	1 82	2 83	76	.00	75 32	75 71	1–25 82	1–27	1–26	1–27
10	790 25	7 15 18	30 28	44 05	57 81	1 06	1 84	2 85	00	00	77 51	77 93	1–27	1–28	1–27 17	1–28
11	922 65	6 12 47	40 74	56 47	72.19	1 08	1 84	2 87	2 99	00	93 85	94 31	1–32 85	1–33	2–33	
12	1,098 73	5 12 59	43 99	60 65	77 28	1 15	1 90	2 91	5 33	00	100 30	100 80	1–23 88	2–24	3–24	
15	1,743 80	3 17 10	55 49	77 98	100 45	1 01	1 78	2 84	09	00	130 56	131 19	1–29 89	2–30	3–30	
16	1,993 24	2 52 29	58 16	81.76	105 35	1 04	1 82	2 87	1 56	00	136 90	137 57	1–29 90	2–33	1–30	2–33
18	2,546 31	2 14 31	58 73	84 46	110 10	1 04	1 82	2 86	.00	1 08	145 76	146 51	1–25 93	3–26	4–26	
20	3,257 26	1 45 32	61 84	90 21	118 59	1 08	1.88	2 93	44	00	156 59	157 42	1–26 92	2–27 1–33	3–27	1–33
24	4,886 16	1 10 21	67 82	100 21	132 59	1 27	1 97	3 00	2 43	00	176 22	177 22	1–32 89	3–33	4–33	

The length of frog from the point to the toe is 6 ft 5 in or 6 42 ft (column 3), and the length of switch rail is 22 ft (column 8) As given in columns 27 and 28, the straight lead rail will be made up of two rails 24 ft long and one rail 23 88 ft long, and the curved lead rail will be made up of three 24-ft rails The tangent distance at the heel of switch is 5 33 ft (column 23), and the coordinates of the quarter and center points for bending the curved lead rail can be taken from columns 17 to 22.

27. Table for Turnouts With Stub Switches.—Dimensions for turnouts with the little-used stub switch are given in Table V. In a stub switch, it is assumed that the switch rail, lead rail, and frog form a continuous circular curve from the

TABLE V

DIMENSIONS OF STUB-SWITCH TURNOUTS

Track Circular From Heel of Switch to Point of Frog Throw = 5½ Inches

Frog Number N	Frog Angle F	Lead to Theoretical Point of Frog L	Radius of Center Line R	Degree of Lead Curve D	Chord From Heel of Switch to Point of Frog Q	Length of Switch Rails S	Length of Frog Theoretical Point to Toe W
1	2	3	4	5	6	7	8
	Deg Min Sec	Feet	Feet	Deg Min	Feet	Feet	Feet
4 0	14 15 00	37 67	150 67	38 46	37.96	11 73	3 17
5 0	11 25 16	47 08	235 42	24 32	47 32	14 65	3 58
6 0	9 31 38	56 50	339 00	16 58	56 69	17 64	4 00
7 0	8 10 16	65 92	461 42	12 26	66 08	20 53	4 42
8 0	7 9 10	75 33	602 67	9 31	75 48	23 48	4 75
9 0	6 21 35	84 75	762.75	7 31	84 88	26 43	6 00
9 5	6 1 32	89 46	849 85	6 45	89 58	27 97	6 00
10 0	5 43 29	94 17	941 67	6 5	94 28	29 37	6 00
11 0	5 12 18	103 58	1,139 42	5 2	103 68	32 31	6 00
12 0	4 46 19	113 00	1,356 00	4 14	113 10	35 17	6 42

heel of switch to the point of frog. The frog angle F is the same as for a split switch. The lead L is the distance from the heel of switch to the theoretical point of frog The radius R and degree D of the center line of the lead curve are given in the fourth and fifth columns The sixth column gives

the length Q of the chord from the gauge side of the outer rail at the heel of switch to the point of frog When the switch is set for the main track the switch rails are straight, and when the switch is thrown for the turnout the switch rails are assumed to conform to the curvature of the lead curve The length S of the switch rails required to join the lead curve with a throw of $5\frac{1}{2}$ inches is given in column 7 A switch rail longer than 30 or 33 feet is impracticable For a shorter switch rail, the rail may be of standard length but left free only for the given distance from the head-chair, the remaining part of the rail being securely spiked to the ties The last column of the table gives the length of frog from the theoretical point to the toe

EXAMPLE —Find the dimensions of a stub-switch turnout with a No. 6 frog

SOLUTION —From the third column of Table V the lead is 56 5 ft, and, from the fourth column, the radius of the center line of the turnout curve is 339 ft The length of the switch rails from column 7 is 17 64 ft, and the distance from the point of frog to the toe is 4 ft Therefore, the length of straight lead rail equals 56 5 − 17 64 − 4 = 34 86 ft As this is longer than the usual length of rail, two rails of approximately equal length should be used The chord of the turnout rail from the heel of switch to the point of frog is found from column 6 to be 56 69 ft The length of the curved lead rail equals 56 69 − 17 64 − 4 = 35 05 ft. As the rails are assumed to form a continuous circular curve, the curved lead rail can be laid out by quarter and middle ordinates from the chord.

EXAMPLES FOR PRACTICE

1 Find from Table IV the dimensions of a point-switch turnout with a No. 16 frog Ans $L_1 = 136\ 9$, $W = 8$, $S = 33$, $T_s = 1\ 56$, straight lead rail (1 — 29 9 and 2–33), and curved lead rail (1–30 and 2–33).

2 Find from Table V the dimensions of a stub-switch turnout with a No. 8 frog. Ans $L = 75\ 33$, $R = 602\ 67$, $S = 23\ 48$, $W = 4\ 75$, $Q = 75\ 48$, straight lead rail = 47.1, and curved lead rail = 47 25

TURNOUT CONSTRUCTION

28. Turnout Ties and Switch Timbers.—Occasionally a turnout is laid on ordinary ties alternating with the main-track ties, but the usual plan is to use timbers long enough to carry all four rails The long ties should be used from the point of switch to a point far enough beyond the frog to allow the side track to be laid on ordinary ties, clear of the main-track ties Headblocks may be 9 in by 12 in, 16 feet long, and the switch timbers are 7 in. by 9 in These timbers are usually spaced 19 or 20 inches between centers, and under the frog the spacing is 18 inches The ties increase in length as they get farther from the switch, the ends of all being in line outside of the unbroken rail of the main track The lengths usually increase by 6 inches, several ties in a group having the same length. For ordinary track-ties 8½ feet long, the maximum length of switch timber is 16 feet 6 inches and for 8-foot ties, the longest timbers are 15 feet 6 inches In a turnout with a No 11 frog and 8½-foot track-ties, the list of timbers recommended by the American Railway Engineering Association is given in Table VI.

TABLE VI

SWITCH TIMBERS FOR NO. 11 TURNOUT

Timbers	Length Ft	In	Timbers	Length Ft	In	Spacings
2 headblocks	16	0	4	13	0	10 of 19 in
12 timbers	9	0	4	13	6	21 of 20 in.
10	9	6	3	14	0	9 of 19 in
8	10	0	3	14	6	13 of 20 in.
5	10	6	2	15	0	5 of 18 in
5	11	0	3	15	6	(5th at frog)
5	11	6	3	16	0	10 of 20 in
3	12	0	3	16	6	4 of 21 in.
3	12	6	—			5 of 20 in
			78			

Heel of switch for 22-foot switch rail is between timbers 14 and 15 Point of frog is on timber 59 Spacings begin at center of first headblock The fifth 18-inch spacing is in front of the tie under the point of frog

No exact rule is used for the distance from the point of frog to the last long timber, but its value in inches for $8\frac{1}{2}$-foot track-ties is approximately equal to 36 times the frog number For example, by the rule, the distance for a No. 11 frog equals $36\times11=396$ inches, from the spacings of the timbers given in the last column of Table VI, the distance equals $10\times20+4\times21+5\times20=384$ inches Obviously, the distance from the headblock to the last long timber is equal to the lead of the turnout plus the distance from the point of frog to the timber; for a No 11 frog, it is equal to $93.85\times12+396=1,522$ inches, or 126 feet 10 inches

29. Rules for Switch Timbers.—Approximate rules for the number and length of switch timbers are as follows:

1. To find the number of long ties required for any turnout, reduce to inches the distance from the headblock to the last long timber beyond the frog, and divide this distance by the average number of inches from center to center of timbers

2 To find the lengths of switch timbers, determine the length of the tie next to the headblock and the length of the last long tie behind the frog Subtract the former length from the latter and divide the difference, in inches, by the number of long timbers in the turnout The quotient will be the theoretical increase in length for each timber to bring the ends of the timbers in proper line on both sides of the track. However, as explained in the preceding article, it is general practice not to vary the length with every timber, but to have several ties of the same length in a group

EXAMPLE.—Find the number of long ties required for a turnout with a No. 8 frog; the average distance from center to center of ties is $19\frac{3}{4}$ inches and the track ties are 8 feet 6 inches long

SOLUTION.—The lead is 67 65 ft, or 812 in, and the distance from the point of frog to the last long timber equals $36\times8=288$ in Hence, the distance from the headblock to the last timber equals $812+288=1,100$ in Since the average distance between centers of timbers is $19\frac{3}{4}$ in, the number of long timbers equals $\frac{1,100}{19\ 75}=56$ Ans

30. Placing Turnout.—When putting a turnout in an existing track, the first step is to locate the point of frog and

the point of switch, the distance between them being equal to the lead It will avoid the cutting of a rail if the toe of frog or the heel of frog is placed at a joint in the existing track and, therefore, if possible, such a location of the frog should be selected However, another important consideration is that the rail joints in the main track must be clear of the switch point and guard-rail, if the existing joints of the main track interfere with the work, new rails must be laid with the joints properly placed

After the positions of the point of switch and point of frog have been selected, the ballast between the ties is removed to a sufficient depth to permit placing of the turnout ties, the foreman having a list of their lengths and spacings The headblock is placed with its center line about $1\frac{1}{2}$ inches back of the point of switch and with its end in line with the ends of the main-track ties If the headblock is composed of two pieces, they are placed in position to allow the head-rod to come between them The main-track ties should not be disturbed more than is necessary to locate the headblock properly The slide plates are then placed on the headblock under the rails, and a rail brace is spiked outside of the unbroken main-track rail A spike is partly driven against the inner side of the rail so as to prevent the headblock from slipping outwards All the ties for the switch and frog are next placed, the main-track ties being shifted when necessary to obtain proper spacing Then the rest of the slide plates, tie-plates, and guard-rail base plates are placed under the rails and spiked, and the necessary rail braces are spiked against the main rails While this is being done the old ties are adzed to a level bearing where necessary The guard-rail is next placed opposite the location for the point of frog and is secured with clamps and braces or bolts

After a rail has been bent to form the knuckle on the turnout side, and the lead rails have been cut to the required lengths, as taken from Table IV, the turnout stock rail, the straight lead rail, and the frog are bolted together and laid on the ends of the ties, ready to be installed When all is in readiness, a flagman is sent out in each direction to stop trains The old track is

then cut, the old main rail being thrown outwards The switch rail, turnout rail, and straight lead rail are then put in place At the point of switch a track gauge is placed on the rails and the switch rail and turnout rail are brought together, a rail brace being spiked outside the turnout rail and the switch point being held in position by a spike partly driven on its inner side The gauge is then placed at the heel of the switch rail, which is spiked With a lining bar the turnout rail is shifted outwards and spiked at the heel to give the required heel distance, usually $5\frac{1}{2}$ or $6\frac{1}{2}$ inches over gauge lines of the rails. The remainder of this rail is then fully spiked The old ties are now removed, the new switch ties are tamped, and the main track is brought to proper line and surface. Trains may then be allowed to pass

The curved lead rail and its connecting switch rail are next placed, and the tie-rods are bolted up and adjusted to give the proper throw at the head-rod When this is done, the switch is thrown for the turnout, trains being flagged and stopped, and the heel of the turnout switch rail is spiked in proper position through the plate on which it rests The switch is thrown for the main track and the rails are spiked in position to insure safety for trains until the switchstand is placed The curved lead rail is then lined and held temporarily by spikes partly driven while the tie-plates are slipped under it and fully spiked The curved lead rail can be lined by using the coordinates for the quarter and center points given in columns 17 to 22 of Table IV Subtract from the values of Y, Y_1, and Y_2 the distance from the gauge of the rail head to the outside of the rail flange, mark the points on the ties, and spike the rail to these marks The turnout stock rail is adjusted at track gauge from the curved lead rail, and is spiked in position The rails of the turnout are laid to exact gauge as far as the point of frog, unless the gauge has been widened owing to the sharpness of the curve Beyond the point of frog the curve may be allowed to vary in gauge a little to prevent a kink from showing opposite the frog

Placing the guard-rail, with its base plate and braces, completes the side-track connection The side of the guard-

rail that comes in contact with the car wheels should be placed 4 feet $6\frac{5}{8}$ inches from the gauge line of the frog This gives a space of $1\frac{7}{8}$ inches between the main rail and the guard-rail In case the gauge is widened at the frog the flangeway between the main rail and the guard-rail is widened an equal amount If the gauge is widened $\frac{1}{2}$ inch, the guard-rail is placed 4 feet $6\frac{1}{8}$ inches from the gauge line of the frog

In placing the switchstand, it is first set on the headblock and the connecting-rod is connected to the shaft and the switch head-rod. The switch is then opened so that the points are equally distant from the gauge sides of the turnout stock rail and main stock rail, the switchstand drop-lever being held in a vertical position while making the measurements of these distances After insuring that the stand is parallel with the main track, it is spiked to the headblock, and any necessary adjustments are made in the switchstand connections to make the rails fit properly against the stock rails

EXAMPLE FOR PRACTICE

If ties are 8 feet 6 inches long and the average distance between their centers is $19\frac{1}{2}$ inches, how many long timbers are required for a turnout having a No 10 frog? Ans 66

TURNOUTS FROM CURVED TRACKS

31. General Remarks.—The theoretical formulas for the dimensions of point-switch turnouts from curved tracks are necessarily complicated However, a turnout from a sharp curve is used only under special conditions, then each case is treated as an individual problem, and the dimensions of the turnout are adjusted to suit those conditions The best way to solve the problem is to make a drawing of the layout to a very large scale, such as 1 inch = 10 feet, or 1 inch = 20 feet, and measure the various dimensions A fairly considerable variation in the length of lead is of little importance and, on existing track, the location is governed to a large extent by the position of rail joints, so that unnecessary cutting of rails may be avoided

The frog rails are straight, but for practical purposes it is sufficiently accurate to consider both the main track and

turnout as continuous curves from the point of switch to the point of frog The switch rails are usually laid straight, and it is left for traffic to bend them approximately to the curvature of the stock rails In furnishing materials for the lead rails, and bending them, the necessary values are determined according to the assumptions discussed in the following articles

32. Degree and Radius of Lead Curve.—For practical purposes, the difference in sharpness between a curved main track and the lead curve of a turnout may be taken equal to

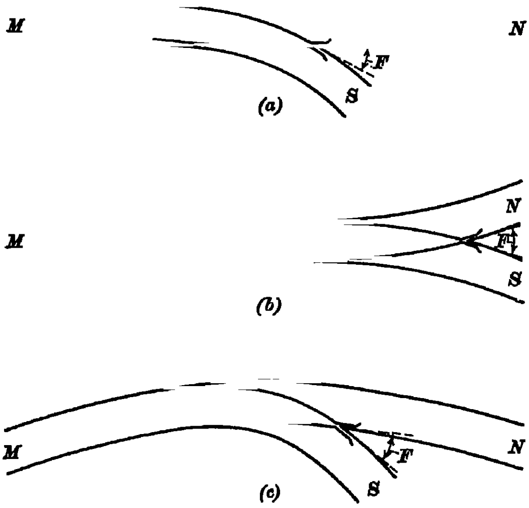


FIG 13

the degree of the practical lead curve for a turnout from a straight track with the same frog number Thus, if MN, Fig. 13, is the main track, MS is the turnout, and F is the frog angle, then the degree of the lead curve can be found by one of the following formulas

$$D' = D - D_m \qquad (1)$$

$$D' = D + D_m \qquad (2)$$

in which D' = required degree of lead curve;

D = degree of lead curve taken from Table IV for given frog number;

and D_m = degree of curve of main track.

Formula **1** is used when the turnout is from the outer side of the main track as in Fig 13 (*b*), and formula **2** is for a turnout from the inner side of the main track as in (*c*) If D_m is equal to D in (*b*), the degree of curve of the turnout is zero and the turnout is straight Then the conditions will be as shown in (*a*), but MS will be the main track and MN, the turnout If the main-track curve is so sharp, or the frog angle is so small, that D_m is greater than D, the turnout in (*b*) will curve in the same direction as the main track; the condition is represented in (*c*), but MS is the main track and MN, the turnout For example, if a turnout with a No 8 frog is to be run from the outside of a 4° curve, as in (*b*), the degree of the lead curve is approximately $11° 45' - 4° = 7° 45'$ If a turnout with a No. 12 frog is to be run from the inside of a 2° curve, as in (*c*), the degree of the lead curve may be taken as $5° 15' + 2° = 7° 15'$. It is sufficiently accurate to take the curvature to the nearest quarter of a degree In all cases the radius R' of the lead curve can be found from the degree of curve D' by the formula $R' = \frac{5730}{D'}$, since the degree of curve is only approximately correct.

33. Lead.—There is a difference between the theoretical lead for a turnout from a curved track and that for a turnout from a straight track with the same frog number. In practice, however, most roads use the same dimensions for turnouts on curved track as for those on straight track, except in the rare case of a very sharp main-track curve, then the lead would be determined by plotting the layout.

When the turnout is from the inside of a curve, as in Fig 13 (*c*), the closures of the lead rails can be taken from columns 27 and 28 of Table IV. But if the turnout is from the outside of a curve, as in (*b*), the main-track lead rail is longer, and the turnout lead rail is shorter than for a turnout from a straight track, even though the lead remains unchanged The difference between the lengths of the straight and curved lead rails for a turnout from a straight track is small and, therefore,

the adjustment of the lengths for a turnout from a curve can be made by means of the formula

$$c = \frac{D}{D+D'} \times e$$

in which c = correction to be added to length of main-track lead rail and subtracted from length of turnout lead rail,

D = degree of main-track curve;

D' = degree of lead curve;

e = difference between lengths of straight and curved lead rails for turnout from straight track

In the first example of the preceding article, the frog number is 8, the degree D of the main-track curve is 4°, and the degree D' of the lead curve is 7° 45′, or 7 75° From columns 27 and 28 of Table IV, the difference e between the lengths of the straight and curved lead rails for a turnout from a straight track is 2 foot Hence, the increase in the length of the main-track lead rail and the decrease in the length of the turnout lead rail is $c = \frac{4}{4+7\ 75} \times 2 =\ 07$ foot. The main-track lead rail would be composed of one 30-foot rail and one 16 47-foot rail and the turnout lead rail would consist of one 30-foot rail and one 16 53-foot rail In this case, since 16 47+16 53=33 00, these two partial rail lengths can be obtained by one cut of a 33-foot rail Sometimes, in order to avoid decimals of a foot in one of the partial rail lengths, the lengths of the leads may both be changed an equal amount For instance, if the calculated lengths are 32 97 and 32 88, it would be convenient to add 03 to each and make them 33 and 32 91, respectively This change would not appreciably affect the lead or curvature

The lead rails are usually bent to shape by sighting without measurements Sometimes, a few points on each lead rail are located by ordinates from the chords between the heels of switch and toes of frog, the chord lengths are equal to the closures for the lead rails, the radius R of the main track is known, and the radius R' of the lead curve is found by the method explained in the preceding article.

EXAMPLES FOR PRACTICE

1 A turnout with a No 11 frog is to be run from the inside of a 3° curve Find (*a*) the degree and (*b*) the radius of the lead curve

Ans $\begin{cases}(a)\ 9°\ 15'\\(b)\ 619\text{ ft.}\end{cases}$

2 A turnout with a No 10 frog is to be run from the outside of a 6° curve Find (*a*) the degree and (*b*) the radius of the lead curve.

Ans $\begin{cases}(a)\ 1°\ 15'\\(b)\ 4{,}584\text{ ft}\end{cases}$

3 In example 2, find (*a*) the calculated closures for the lead rails and (*b*) the practical closures

Ans $\begin{cases}(a)\begin{cases}\text{Main-track rail, one 28, one 27 14}\\\text{Turnout rail, one 28, one 27 03}\end{cases}\\(b)\begin{cases}\text{Main-track rail, one 28, one 27.11}\\\text{Turnout rail, one 28, one 27}\end{cases}\end{cases}$

CONNECTING TRACKS

CONNECTING CURVES

34. Connecting Curve Between Two Parallel Straight Tracks.—Let WA, Fig 14, be a main track and WM, a turnout. If the turnout is to be connected with a side track EB parallel to the main track, a curved track HE,

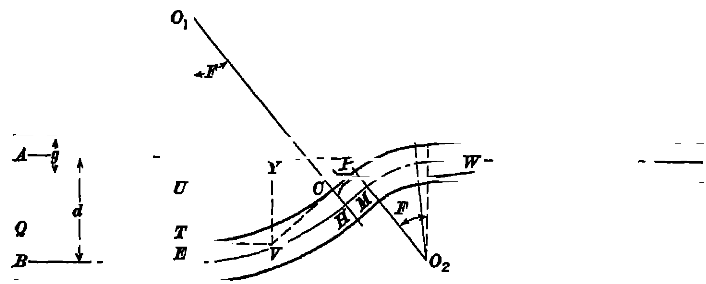


Fig 14

called a *connecting curve*, must be introduced. The frog number N and the distance d between the center lines of the parallel tracks must be known; it is required to compute the radius r of the center line of the connecting curve and the

distance PU from the theoretical point of frog to the point on the main track opposite the end of the connecting curve. The distance d is usually 13 feet Produce the inner rail QT of the side track and the frog rail PC to intersect at V Since TV and CV are tangents to the connecting curve, and F is the angle between the tangents,

$$CV = O_1C \tan\frac{F}{2}$$

If g is the gauge of track, $O_1C = r - \frac{g}{2}$ and $CV = \left(r - \frac{g}{2}\right)\tan\frac{F}{2}$.

By formula 2, Art 22, $\cot\frac{1}{2}F = 2N$, from which $\tan\frac{1}{2}F = \frac{1}{\cot\frac{1}{2}F} = \frac{1}{2N}$. Hence,

$$CV = \left(r - \frac{g}{2}\right)\frac{1}{2N}$$

The distance from the theoretical point to the heel of frog is PC or K. Then $PV = PC + CV = K + \left(r - \frac{g}{2}\right)\frac{1}{2N}$, and

$$VY = PV \sin F = \left[K + \left(r - \frac{g}{2}\right)\frac{1}{2N}\right]\sin F$$

But VY is also equal to $d - g$ Therefore,

$$K \sin F + \frac{r}{2N}\sin F - \frac{g}{4N}\sin F = d - g$$

and $$r = \frac{2N(d-g)}{\sin F} - 2NK + \frac{g}{2} \qquad (1)$$

$$PU = PY + YU$$

but $$PY = VY \cot F = (d-g)\cot F$$

and $$YU = TV = CV = \left(r - \frac{g}{2}\right)\frac{1}{2N}$$

Hence, $$PU = (d-g)\cot F + \left(r - \frac{g}{2}\right)\frac{1}{2N} \qquad (2)$$

EXAMPLE —The distance between the center lines of two parallel, straight, standard-gauge tracks is 13 feet The tracks are to be connected by a turnout with a No 8 frog, and a connecting curve Find the radius of the connecting curve and the distance PU, Fig 14.

SOLUTION —In formula **1**, $N=8$, $d=13$, $g=4\ 708$, $\sin F=12452$ (Table II), and $K=8\ 75$ (Table IV)

$$\text{Then, } r=\frac{2\times 8\times(13-4\ 708)}{12452}-2\times 8\times 8\ 75+\frac{4\ 708}{2}=927\text{ ft}\quad\text{Ans.}$$

By formula **2**,

$$P\ U=(13-4\ 708)\times 7\ 969+(927-2\ 35)\times\frac{1}{16}=123\ 87\text{ ft}\quad\text{Ans}$$

35. A connecting curve between parallel curved tracks is never used if it can be avoided In an occasional instance where it is necessary, the dimensions are found best by plotting the layout to a large scale

EXAMPLE FOR PRACTICE

The distance between the center lines of two parallel, straight, standard-gauge tracks is 13 feet Find the radius of the connecting curve and the distance PU, Fig 14, (*a*) if a No 12 frog is used and (*b*) if a No. 16 frog is employed.

$$\text{Ans}\begin{cases}(a)\ r=2{,}105\text{ ft},\ P\ U=186\ 94\text{ ft}\\(b)\ r=3{,}740\text{ ft},\ P\ U=249.35\text{ ft}\end{cases}$$

CROSSOVERS

36. Definition of Crossover.—A *crossover* is a diagonal track connecting two parallel tracks and enabling trains to pass from one track to the other It consists of two turnouts

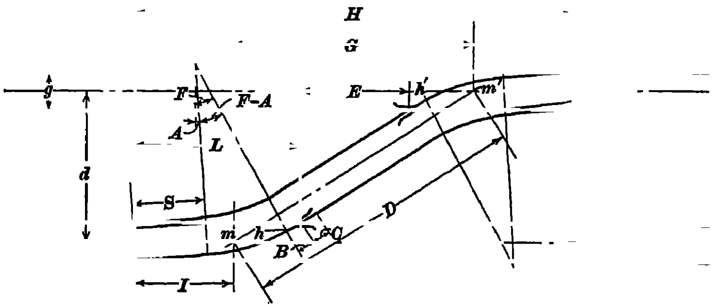


FIG. 15

placed in opposite directions with the frogs connected preferably by a straight track tangent to both turnout curves, as shown in Fig. 15. A short crossover is made by continuing

the turnout curves beyond the frogs to form a reversed curve as in Fig 16 Although a reversed curve requires less length of track and may be used to meet special conditions, the

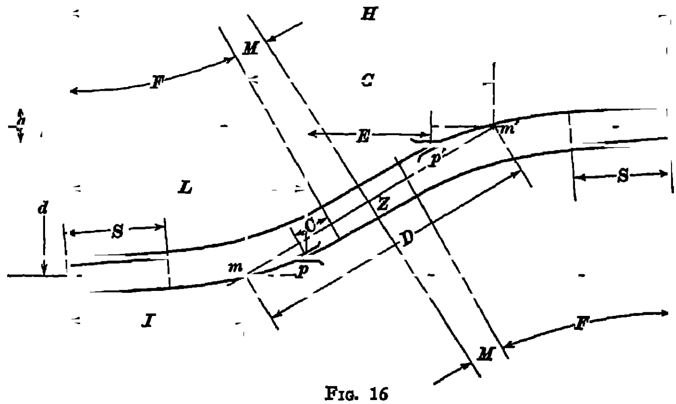


FIG. 16

straight track makes riding easier and reduces wear because of the fact that the car trucks, after passing one curve, adjust themselves on the tangent and thus take the second curve more smoothly

37. Crossover With Straight Connecting Track.—When the frogs of a crossover are connected by a straight track, as in Fig 15, the two turnouts must have the same frog angle; therefore, the two halves of the crossover are alike The dimensions of the turnouts from the points of switches to the heels of frogs can be taken from Table IV All the other values required for the layout are given in Table VII. The distances are measured from the actual point of switch and the actual point of frog, and all distances are in feet

The values of D, E, G, and H in the table are for tracks spaced 13 feet between the center lines, that is, the distance d in Fig 15 is 13 feet For each foot of wider spacing, add to the dimensions E, G, and H the correction given in line 8 and to dimension D the correction in line 13, for each foot of closer spacing subtract the corrections. For example, if the spacing is 15 feet, add twice the corrections in the table, and if the spacing is 12 feet 6 inches, subtract half the corrections

TABLE VII

DIMENSIONS OF CROSSOVERS

Dimension	Frog Number								
	6	7	8	10	11	12	16	20	24
Toe to actual ½-inch point, B	4 25	4 71	5 08	6 42	6 46	6 92	8 67	10 50	12 33
Heel to actual ½-inch point, C	6 75	7 79	8 42	10 08	11 04	11 58	15 33	18 50	22 17
Total length of frog, $B+C$	11 00	12 50	13 50	16 50	17 50	18.50	24 00	29.00	34 50
Length of switch rail, S	11 00	16 50	16 50	16 50	22 00	22 00	33 00	33 00	33.00
Distance between points of frog, E	20 47	24 04	27 60	34 68	38 20	41 74	55 82	69 85	83 88
Distance between intersections, G	77 46	90 54	103 59	129 68	142 71	155 73	207 80	259 84	311 86
Distance between points of switch, H	116 43	148 24	163 56	190 54	226 82	243 34	330 96	384.69	438 32
Correction for E, G, and H	5 96	6 96	7 97	9 98	10 98	11 98	15 98	19 99	23 99
Point of switch to intersection, I	19 49	28 85	29 99	30 43	42 06	43 81	61 58	62 43	63 23
Lead to actual point of frog, L	47 98	62 10	67 98	77 93	94 31	100 80	137 57	157 42	177 22
Actual point to theoretical point of switch	46	69	69	69	92	92	1 38	1 38	1 38
Diagonal distance between center lines, D	78 54	91 47	104 40	130 33	143 30	156 27	208 21	260 16	312 14
Correction for D	6 04	7 04	8 03	10 03	11 02	12 02	16 02	20 01	24 01

EXAMPLE.—Find the dimensions of a crossover between two straight tracks, 13 feet center to center, if the turnouts have No 11 frogs and they are connected by a straight track

SOLUTION —From Table IV, the frog angle F is 5° 12′ 18″, the length S of switch rail is 22 ft , the switch angle A is 1° 18′ 8″, the radius R of the center line of the practical lead curve is 922 65 ft , the lead L to the actual point of frog is 94 31 ft , and the closures of the straight and curved lead rails are found in columns 27 and 28 From Table VII, the distance E between the actual frog points measured parallel to the main tracks is 38 20 ft , the distance H between the actual switch points is 226 82 ft , and the distance I from the point of switch to the intersection of the main track and the connecting track is 42 06 ft The distance D between the points of intersection can be used as a check on the work and should be 143 30 ft

38. Crossover With Reversed-Curve Connection.—A reversed-curve crossover, Fig 16, is especially adaptable when the frog angle is small and the two parallel tracks are far apart. Usually, the two turnouts have the same frog number and the two branches of the curve have the same radius, which is that of the lead curves. The central angle of each half of the reversed curve, from the heel of frog to the point of reversal Z, is denoted by M Hence, the angle between each main track and the line $m\,m'$, which is tangent to the reversed curve at Z, is equal to $F+M$ For such conditions the dimensions of the crossover can be determined by the following formulas in which R, the radius of the center line of the reversed curve, is taken from Table IV; r, the radius of the outer rail, is equal to $R+\frac{g}{2}$.

$$\cos (F+M) = \frac{r \cos F + K \sin F - \frac{d-g}{2}}{R} \qquad (1)$$

$$E = 2\,[R \sin (F+M) - r \sin F + C \cos F] \qquad (2)$$

$$D = \frac{d}{\sin (F+M)} \qquad (3)$$

$$G = \frac{d}{\tan (F+M)} \qquad (4)$$

$$H = 2\,L + E \qquad (5)$$

$$I = \frac{H-G}{2} \qquad (6)$$

EXAMPLE —Compute the dimensions of a crossover between two tracks, 15 feet center to center, using turnouts with No. 20 frogs and a reversed-curve connecting track

SOLUTION —The dimensions for the turnouts can be taken from Table IV. In this case, $F=2°\ 51'\ 51''$, $R=3{,}257\ 26$ ft, $g=4\ 71$ ft, $r=3{,}259\ 61$ ft, $K=19\ 33$ ft, and $L=157\ 42$ ft Then by formula **1**,

$$\cos(F+M)=\frac{3{,}259\ 61\cos 2°\ 51'\ 51''+19\ 33\sin 2°\ 51'\ 51''-\dfrac{15-4\ 71}{2}}{3{,}257\ 26}$$

whence, by the use of a table of natural functions, $F+M=3°\ 27'$

By formula **2**, $E=2\,(3{,}257.26\sin 3°\ 27'-3{,}259\ 61\sin 2°\ 51'\ 51''+18\ 5\cos 2°\ 51'\ 51'')=103\ 23$ ft

By formula **3**, $D=\dfrac{15}{\sin 3°\ 27'}=249\ 25$ ft

By formula **4**, $G=\dfrac{15}{\tan 3°\ 27'}=248\ 80$ ft.

By formula **5**, $H=2\times 157\ 42+103\ 23=418\ 07$ ft.

By formula **6**, $I=\dfrac{418\ 07-248\ 80}{2}=84\ 64$ ft

If a straight connecting track were used, the distance E would be $69\ 85+2\times 19\ 99$ or 109 83 ft Hence, by using a reversed curve, the length of track saved equals $109\ 83-103\ 23=6\ 60$ ft.

39. Crossover Layout.—In laying out a crossover, the location of one turnout is first selected to suit the existing track After one frog point has been placed, the other can be readily located by measuring the distance E parallel to the main tracks Each turnout can be put in separately according to the method described in Art **30.**

It is customary to use very long ties laid perpendicular to the main tracks for the part of the crossover between the toes of the frogs, as from h to h' in Fig 15 Then the main tracks and the connecting track all rest on the same ties For tracks 13 feet apart, the length of these ties should be 21 feet 6 inches If the connecting track is straight its center line can best be located by measuring the distance I from each actual point of switch along the center line of the main track to m and m', Fig 15, and then joining the two points thus found by a straight line When the connecting track is a reversed curve, the distance I is measured along the center line of each main track as in the case of a straight connection.

The line $m m'$, Fig 16, joining the two points thus located is tangent to the center line of the reversed curve at the point of reversal Z The point Z is then located on this line at a distance $\frac{D}{2}$ from either m or m' Both branches of the reversed curve can then be laid out best from Z and the common tangent $m m'$, rather than from the frog points p and p'

40. A crossover between parallel curved tracks is not good practice and should be used only when absolutely necessary Since the theoretical formulas for the dimensions are too complicated for practical use, the problem would be best solved by making a plot of the layout to a large scale as in the case of a turnout from a curved track

EXAMPLES FOR PRACTICE

1 Find the dimensions of a crossover between two tracks, 13 feet 6 inches from center to center, if the turnouts have No 8 frogs, and the connecting track is straight

Ans $\begin{cases} F=7° 9' 10'', S=16\ 5 \text{ ft}, A=1° 44' 11'', R=487\ 48 \text{ ft}, L=67.98 \text{ ft.} \\ E=31\ 59 \text{ ft}, H=167\ 55 \text{ ft}, I=29\ 99 \text{ ft}, \text{and } D=108\ 42 \text{ ft.} \end{cases}$

2 Compute the dimensions of a crossover between two tracks, 14 feet apart, if the turnouts have No 16 frogs and the connecting track is a reversed curve having the radius of the turnout curves

Ans $\begin{cases} F=3° 34' 47'', S=33 \text{ ft}, A=0° 52' 5'', R=1{,}993\ 24 \text{ ft}, L=137\ 57 \text{ ft}, \\ F+M=4° 8', E=68\ 74 \text{ ft.}, D=194\ 23 \text{ ft}, G=193\ 72 \text{ ft}, H=343\ 88 \\ \text{ft}, \text{and } I=75\ 08 \text{ ft} \end{cases}$

3 Find the difference in the dimension H if a straight connecting track had been used in example 2 Ans 3 06 ft

LADDER TRACKS

41. In yard layouts it is a common requirement to connect a straight main track with a number of parallel and equally spaced side tracks, or *body tracks*, on which cars can be switched or stored. This is done by means of a straight diagonal track, called a *ladder track*, which has a series of turnouts to the body tracks In Fig 17, MN is a main track, MV is a ladder track, and CD and ER are body tracks. As

a rule, the ladder is at the ends of the body tracks, but in some cases it may intersect them

According to the recommendations of the American Railway Engineering Association, the distance between the centers of adjacent body tracks should be from 13 to 14 feet, and the center of the first body track should not be less than 15 feet from the center of the main or other important track, that is, d_1, Fig 17, should not be less than 15 feet, and d_2 should be from 13 to 14 feet Ladder tracks should not be less than 15

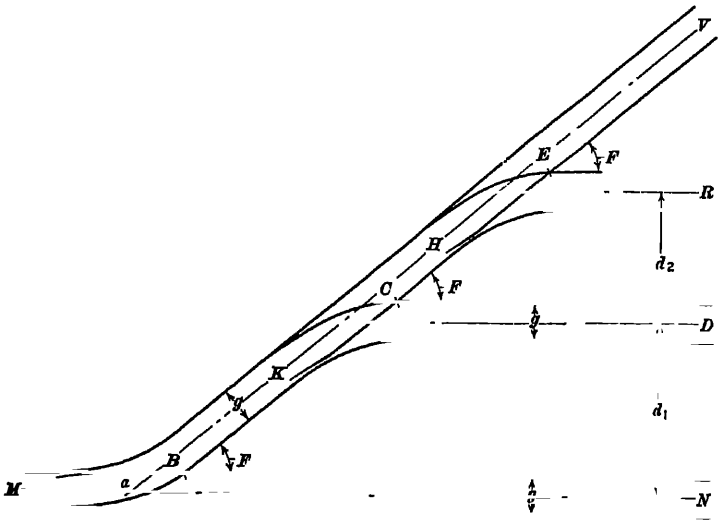


FIG. 17

feet center to center from any parallel track Frog numbers less than 8 should not be used on ladder tracks

Since all the body tracks are parallel, all the frogs have the same number, and all the turnouts are similar, the turnout from the main track to the ladder is included, but, of course, it is in the opposite direction to that of the turnouts to the body tracks The distance between body tracks along the ladder track is equal to the distance D, Table VII, for a cross-over It is evident from Fig 17 that the distances between successive points of frog, as CE, and between successive points of switch, as KH, are also equal to D.

To lay out the ladder, first measure the distance I, Table VII, from the point of switch along the center line of the main track, from the point a thus located, run the ladder $B\,V$ at an angle F with the main track Then locate along $B\,V$ the switch points and frog points for the turnouts to the body tracks as follows $B\,C$ is equal to the distance D in Table VII for a distance center to center of tracks equal to d_1, and $B\,K$ is equal to $B\,C$ minus the lead L, $C\,E$ is equal to distance D for tracks whose distance between centers is d_2, and $C\,H$ is equal to $D-L$ for that condition. The dimensions for all the turnouts are the same and can be taken from Table IV. The body tracks are straight beyond the frogs

EXAMPLE —In a yard layout the first body track is 15 feet from the main track and the body tracks are 13 feet center to center If the turnouts have No 12 frogs, find the distances $B\,K$, $B\,C$, $C\,H$, and $C\,E$ in Fig 17

SOLUTION —From Table VII, for tracks 13 ft apart and No. 12 frogs, $D=156\ 27$, since the correction is 12 02, the distance D for tracks 15 ft. apart equals $156\ 27+2\times 12\ 02=180\ 31$ ft. Hence $B\,C$ is 180 31 ft Ans.

The lead L for a No 12 frog is 100 80 ft, and, therefore, $B\,K=B\,C-L=180\ 31-100\ 80=79\ 51$ ft. Ans

The distance $C\,E$, which is equal to D for tracks 13 ft. apart, is 156 27 ft Ans

Distance $C\,H=C\,E-L=156.27-100\ 80=55.47$ ft. Ans.

EXAMPLE FOR PRACTICE

The first body track in a yard is 15 feet 6 inches from the main track, and the body tracks are 13 feet 6 inches apart Find the distances $B\,K$, $B\,C$, $C\,H$, and $C\,E$ in Fig 17 if the turnouts have No 10 frogs

Ans. $B\,K=77\ 48$ ft, $B\,C=155\ 41$ ft, $C\,H=57\ 42$ ft, $C\,E=135.35$ ft.

TRACK CROSSINGS

CONSTRUCTION

42. Crossings.—At grade crossings of railway tracks special frogs are required at the four rail intersections to provide openings for the passage of wheel flanges along both tracks These are known as *crossing frogs*, and the entire arrangement of rails and frogs, as shown in Fig 18, is called a *crossing* With this construction all wheel treads have to jump two gaps, causing severe pounding at the frogs, con-

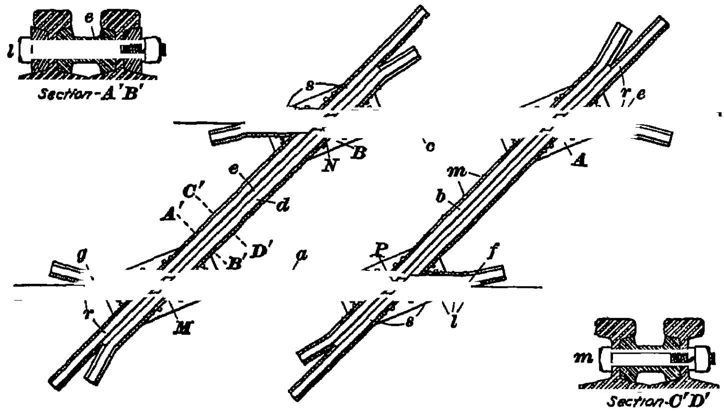


FIG 18

sequently heavy construction and rigid connection of parts are necessary in order to resist the shocks and vibration It is usual to rivet a steel base plate under each frog, but at right-angle crossings the plates are sometimes continuous The guard-rails *a*, *b*, *c*, and *d* extend on all four sides of the crossing, the fillers *e*, *f*, and *g* being fitted between the webs of the guard-rails and track rails to give the necessary width of groove or flangeway, and the rails being bolted together through the

webs by the bolts l and m, the details are shown in sections $A' B'$ and $C' D'$. At each frog the guard-rails and track rails have base plates A and B riveted under the flanges The two sharp end frogs r are similar to turnout frogs and the center frogs s are blunt, as shown. In a right-angle crossing all four frogs are alike

43. Ties and Ballast Under Crossings.—Ties and long switch timbers may be used to support crossings when the tracks intersect at angles less than 50 or 60 degrees, the ties being laid parallel with the short diagonal of the crossing, as $N P$ in Fig 18 For angles between 50 and 90 degrees, ordinary track ties laid in the usual way may be placed in one track, with two heavy timbers or stringers under the rails of the other track More rarely, crossings of 90 degrees have framed together four timbers corresponding to the rails, or even four steel stringers Plenty of good ballast and a well-drained roadbed are essential for keeping crossings in condition; where the ground is soft or traffic is heavy, it may be an advantage to carry the ballast on a concrete slab in the roadbed

44. Crossing Construction.—The crossing usually is built up of steel rails The rails of one track may be continuous, flangeways for the intersecting track being cut through the head only, thus leaving the web and base intact Inserts of hard manganese-steel castings are often used in crossing frogs to reduce the wear and thus lengthen the life of the crossing A single casting may comprise the frog points and wings For very heavy traffic the entire crossing may be a single casting, or it may be built up of castings.

For intersection angles from 90 to 30 or 25 degrees, four complete guard-rails are used as shown in Fig 18, two of these being continuous (with flangeways planed across the heads) and the others framed to them with heavy braces and bolts Where the traffic is heavy, easer rails are placed against the outside of the track rails and in contact with their heads These carry the false flanges of wheel treads which have worn hollow and thus reduce the battering and jolt as the wheels

pass over the frogs. For intersection angles between 18 and 25 or 30 degrees the guard-rails are usually short or not continuous, and for angles less than 18 degrees the easer rails are used only at the frogs Long oblique crossings at angles less than 25 or 30 degrees are undesirable and should be avoided.

45. Special Crossing Devices.—For intersection angles not greater than 8 degrees, the points of the two center frogs are almost directly opposite, and, therefore, it is impossible to place the guard-rails properly Hence there is a possibility of derailment by wheels striking the frog or taking the wrong side of the frog point To meet this condition *movable-point frogs* may be installed, as shown in Fig 19 In this

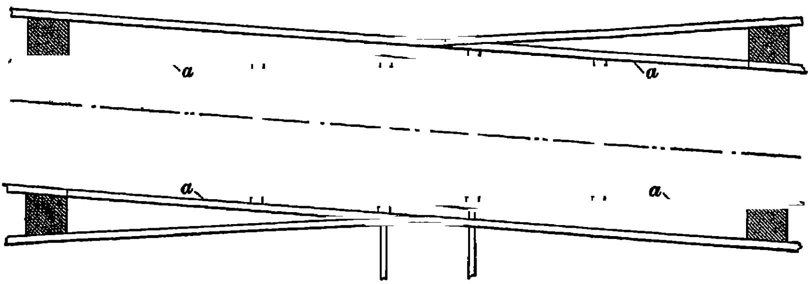


FIG 19

form of a crossing, short point rails *a*, like those of a split switch, are operated from a switchstand or tower, one set of points being opened as the other set is closed.

In yard work, particularly in the yards of passenger stations, it is sometimes desirable to connect a diagonal ladder track with parallel tracks which it intersects, but no room is available for a series of ordinary turnouts. The connection can be made, however, by a *diamond*, or *slip, switch* having all parts contained between the end frogs of the crossing, as shown in Fig 20. Here *A* and *B* are the switch rails for one track, and are connected by the tie-rod *E*; the switch rails *C* and *D* for the other track are connected by the tie-rod *F* At *G* is one of the end frogs, and *H* is one of the center frogs By throwing the switches to the proper positions, a train can be

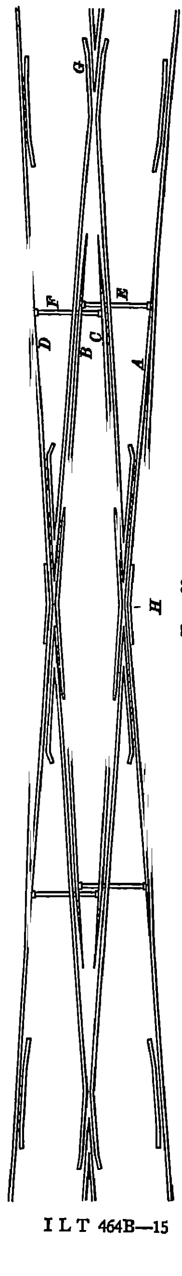


FIG 20

directed to any desired track Slip switches may be either single or double, for connection in one or both directions, the arrangement shown by the drawing being a double switch In occasional cases slip switches are used on main tracks, as at the connection of a double track with a four-track line

For crossing angles near 90 degrees an arrangement has been invented, in which movable frogs are operated by mechanism interlocked with the signal apparatus When the signals for one line are put into position to indicate *proceed*, the movable parts of the crossing frogs are shifted so as to close the flangeways of the other track, and thus give an unbroken rail surface These devices have not yet come into extensive use

DIMENSIONS OF CROSSINGS

46. Dimensions of Straight Crossings. The dimensions of a crossing are the angle between the intersecting center lines and the distance measured parallel to one track between the gauge lines of the other track,

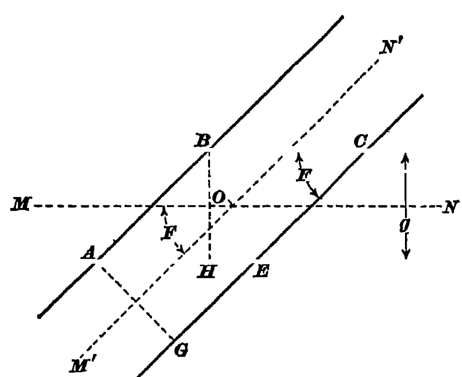


FIG 21

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which is also the distance along a rail between the theoretical frog points, one center and one end, on that rail. Let MN and $M'N'$, Fig 21, be the center lines of two tracks intersecting at O, and let F be the angle between the center lines Then, since the sides of each end frog are respectively parallel to the two center lines, each frog angle will be equal to F

From the triangle $A\,B\,H$,

$$A\,B = E\,C = \frac{B\,H}{\sin\,B\,A\,H} = \frac{g}{\sin\,F} \qquad (1)$$

Similarly, from the triangle $A\,E\,G$,

$$A\,E = B\,C = \frac{A\,G}{\sin\,A\,E\,G} = \frac{g}{\sin\,F} \qquad (2)$$

The lengths of the crossing rails are therefore all equal, that is, $AB = E\,C = A\,E = B\,C$

EXAMPLE —If two straight tracks intersect at an angle of 30°, what are the dimensions of the crossing?

SOLUTION —Each end frog angle F will be 30°. From formulas 1 and 2,

$$A\,B = B\,C = C\,E = E\,A = \frac{g}{\sin\,F} = \frac{4\,708}{5} = 9\,416 \text{ ft} \quad \text{Ans}$$

47. Curved-Track Crossings.—When one or both intersecting tracks are curved the frog angles are all different and the frog rails are curved for their entire lengths Crossings of curved tracks should be used only when absolutely unavoidable, then the dimensions are best determined by plotting the layout to a large scale.

EXAMPLE FOR PRACTICE

Find the dimensions of a straight-track crossing if the angle between the center lines of the intersecting tracks is 60°

Ans $F = 60°$, $A\,B = A\,E = 5\,44$ ft

RAILWAY STRUCTURES AND TERMINALS

RAILWAY BUILDINGS

RAILWAY STATIONS

PASSENGER STATIONS

1. Main Considerations.—In the design of a passenger station the general layout, including the track and platform arrangement, is mainly in the hands of the engineer The architect takes a large part in the design of the building itself, the importance of his work increasing with the size and importance of the structure However, the general plan of the building, and especially the arrangement of the station facilities, is subject to the approval of the engineer and the operating officers, in order to insure convenience and efficiency in conducting the station business The size of the building and the character of the facilities to be provided will vary with the size of the town or city, and the amount of business to be handled at the station

For operating purposes a railway is divided into divisions that are generally about 100 miles long. Stations at division points usually have an upper floor with rooms for the division officers

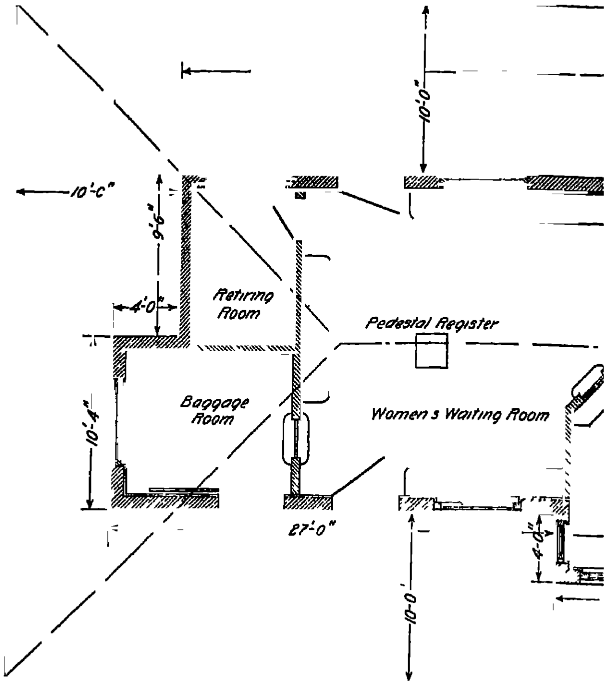
2. Arrangement of Station Facilities.—For passenger stations of the smaller class, the principal requirements are the waiting room, ticket office, baggage room, and express room. A common arrangement consists of two waiting rooms, one

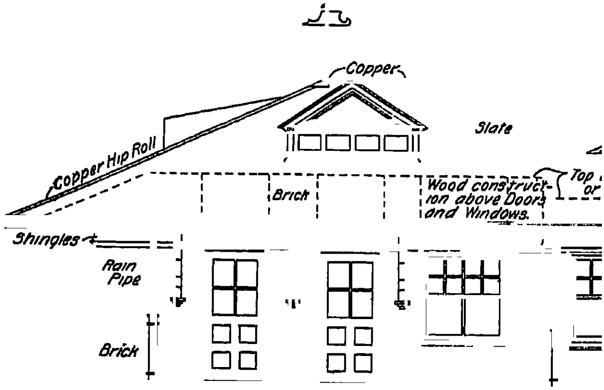
for men and one for women, partly or entirely separated by the ticket office. If the waiting rooms are only partly separated by the ticket office, a single ticket window may be placed in the corridor or passageway between them, but, if they are entirely separated, a ticket window is required in each room. The American Railway Engineering Association recommends a single general waiting room having at one end two toilet rooms and a women's room; one toilet is entered from the waiting room and the other from the women's room At the other end of the building is the ticket office, located on the track side, with the baggage and express room in the rear of the ticket office Certain Southern states require separate accommodations for white and for colored people Toilet rooms should be provided at stations when sewer connections are available. Small country stations have outhouses with cesspools or chemical toilets, the latter being preferable Small stations are usually heated by stoves, while large ones have steam or hot-water systems with radiators

As a rule the ticket office projects beyond the track front of the building and has side windows in order that the station agent, who is usually also the telegraph operator, may have a good view of the platform and trains, and may be able to talk to trainmen on the platform A train-order signal is placed either on the roof of the building or on a post in front of the station, and is operated by the agent in accordance with orders from the train dispatcher This signal is installed even where the block-signal system is employed, its use being to notify enginemen of trains when the station agent has orders for them.

Frame construction is generally used for small stations, but brick, tile, concrete, concrete blocks, and cement or stucco on steel lathing are also used extensively for both small and medium-sized stations Cost, convenience, comfort, and pleasing appearance are points to be considered in the design of a station.

3. Medium-Sized Stations.—A typical station of medium size is shown in Fig 1; in (*a*) is an elevation of the side





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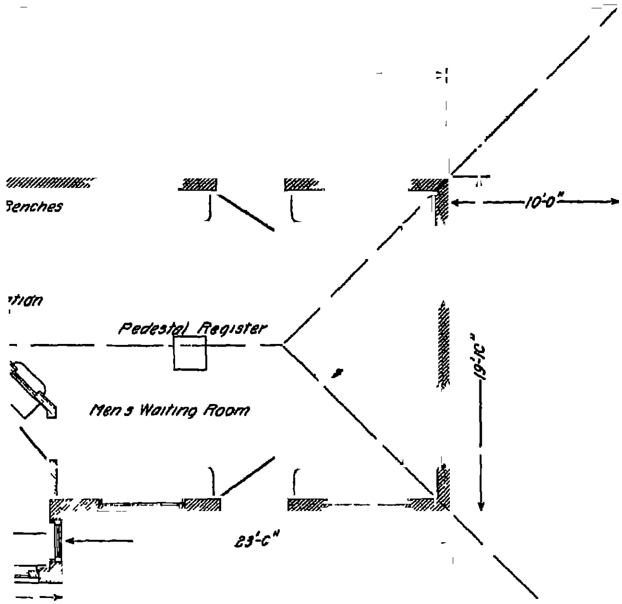
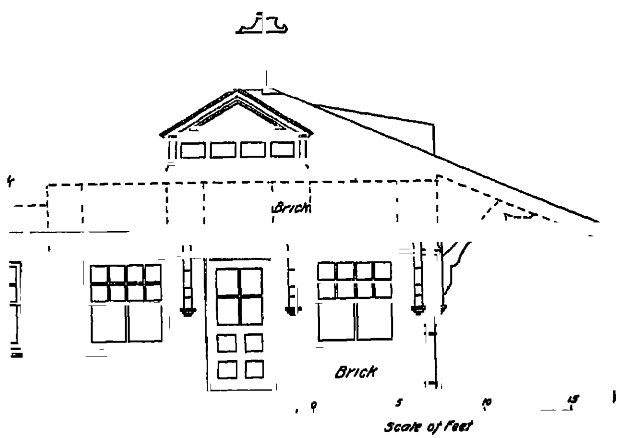

Benches
Pedestal Register
Men's Waiting Room
10'-0"
19'-10"
23'-0"


Brick
Brick
0 5 10 15
Scale of Feet

of the station facing the track, in (*b*) is a plan view of the station, and in (*c*) is a cross-section through the central portion that is two stories high The station has brick walls which carry wooden roof trusses covered with a slate roof. The building has a uniform width of about 37 feet, its length of 313 feet is divided into three portions by two covered passages, or arcades The central portion contains the main waiting room, with the ticket office on the track side (and projecting beyond the building), the baggage room, women's room, smoking room, two toilet rooms, the express room, a baggage check room, a news-stand, and a stairway leading to the second floor The left-hand portion contains the dining room, kitchen, and store room The right-hand portion contains the ice room, rooms for the linemen or telegraph-repair men, and rooms for the car-repair men who inspect passenger trains and freight cars

Tile flooring is used in the waiting room and toilet rooms, maple plank floors in the baggage and express rooms, and cement floors elsewhere On the driveway side of the building is a vehicle porch, and on the track side is a concrete platform 15 feet wide, extending the full length of the building In front of the central portion of the building, this platform is covered by a porch roof. Ordinarily such a station would not have an upper floor, but in this case the central part of the building is two stories high to provide office room for the division superintendent and other officers. The floor of the second story is a concrete slab supported on reinforced-concrete beams, resting on the brick walls.

4. Small Stations.—The small station shown in Fig 2 has the double waiting room arrangement previously mentioned, but with a ticket window for each room instead of a single window in the passageway Toilet rooms are not included in the design, outhouses being provided in this case The roof extends 10 feet beyond the walls of the building and furnishes a broad shelter on all sides.

5. Shelter Sheds.—At roadside stops, as on interurban or country lines, a simple shelter shed is usually provided to

protect waiting passengers from the weather Such a struc-

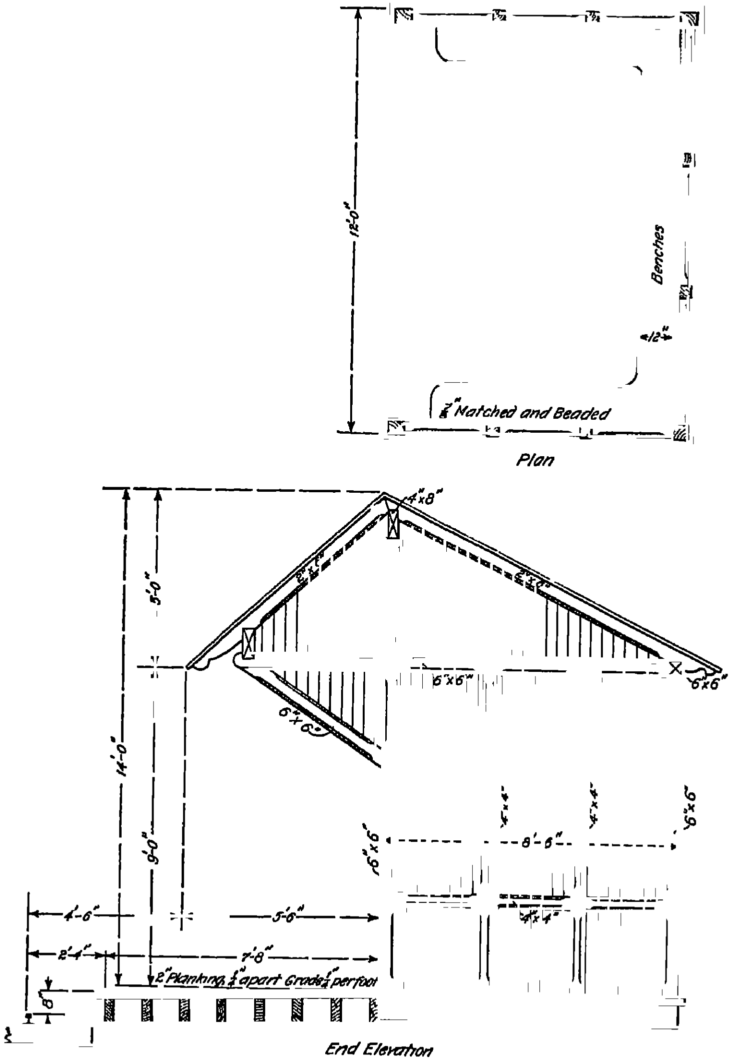


FIG. 3

ture is shown in Fig. 3 Many railroads have standard designs for small stations and shelter sheds

6. Trainsheds.—In stations of large cities the tracks and platforms are usually covered by a trainshed. Formerly lofty steel arch spans extending over the entire width to be covered were favored, but the type of trainshed now in more general use has a low roof supported on cross-girders and intermediate columns as illustrated in Fig 4. The transverse plate girders *a*, used in this case, are slightly arched and are sup-

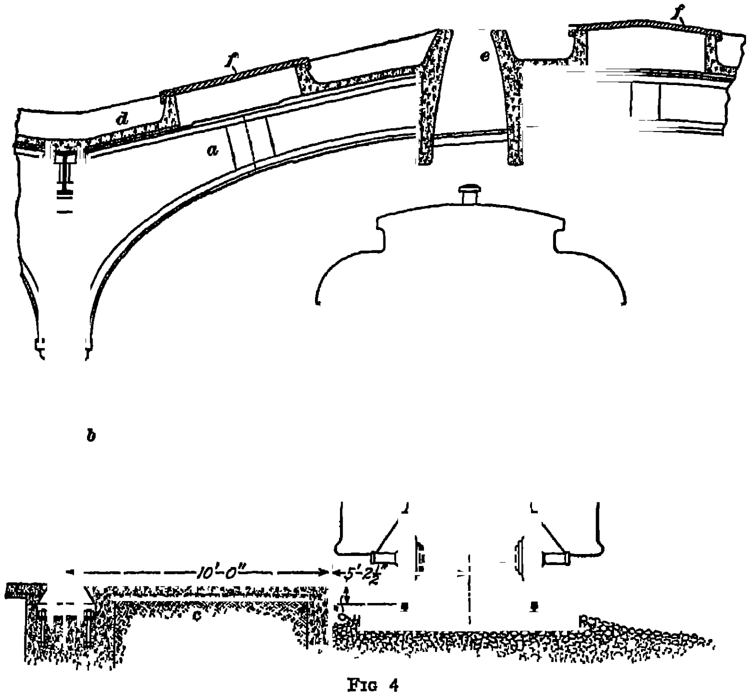


FIG 4

ported on the columns *b*, located along the centers of the platforms *c*. The reinforced-concrete roof *d* is supported on steel purlins attached to the girders. Over each track is a slot, or smoke opening, *e*, which provides for the escape of smoke and steam from the locomotives. These openings are continuous from girder to girder and have vertical sides extending above and below the roof, as shown, to prevent snow and rain from driving on the platforms Such trainsheds

usually have skylights *f* in the roof to provide adequate lighting.

At smaller places and in warm climates the tracks are uncovered and each platform has a low shelter roof.

7. Platforms.—In large stations the platforms are usually 14 to 20 feet wide and the tracks are arranged in pairs with an alternate spacing of 15 feet and 25 to 31 feet between centers. The platforms are placed between the tracks that are spaced 25 to 31 feet between centers The edge of the platform is usually about 5 feet from the center line of the track and 6 to 9 inches above the rail heads A slope of ¼ inch toward the track provides for drainage of side platforms, while those between tracks are crowned so as to drain to both sides

High platforms level with the floors of the cars are used in a few large terminals, generally on elevated and subway lines and on some suburban lines They are usually placed 3 feet 10 inches above the top of the rail, with the edge 5 feet 6 inches from the center line of the track Station platforms are commonly constructed of concrete, with a cement sidewalk finish if outdoors, or covered with asphalt if inside a trainshed Wood plank platforms are used to some extent, especially for small stations Brick laid on a layer of sand on a concrete base and with the joints filled with cement or asphalt is also used in some sections, while plank or concrete is employed for the platforms of elevated lines Filled platforms, used at smaller stations, have cinders, gravel, or stone screenings placed between curb walls of longitudinal timbers, or concrete or stone slabs set on edge These curb walls may be braced on the outside by posts or small stakes, but usually they are anchored into the filling by tie-rods Where there are curbs on each side of the filling, the rods may pass through both lines of curbs Plank platforms will have a longer life if raised far enough above the ground to allow free circulation of air The planks may be nailed to sleepers or sills embedded in a cinder filling.

FREIGHT HOUSES

8. Introductory Remarks.—At small stations, the passenger and freight business may be included in one building, but as a rule there is a separate freight house. This house is located on a siding, termed the *house track*, where cars can be placed in position for loading and unloading without occupying the main track. A house track is also used with a combination freight and passenger station, and is generally placed in the rear of the building.

At most large freight stations there is a team yard, where bulk or carload freight can be handled directly between the wagons or trucks and the freight cars that are being loaded or unloaded. The tracks may be in pairs, spaced alternately 12 feet and 40 or 50 feet between centers, the wide spaces providing for 30- to 40-foot paved driveways between tracks. A lifting device or crane should be provided for transferring heavy or bulky articles.

9. Typical Freight House.—An example of a typical freight house for a division point is shown in Fig. 5. This building is about 40 feet wide and 180 feet long; it has brick walls supporting timber roof trusses for a pitched slate roof, although a flat-roof design is used almost as extensively. The floor of the building is 4 feet above the top of the rails and is level with a platform on the track side. This platform extends along the full length of the building and for a distance of 250 feet beyond one end, being covered throughout its entire length by a shelter roof. The platform beyond the end of the building is 24 feet wide and is covered with a canopy roof to protect freight as it is handled in and out of the house. On the opposite side of the building is a paved driveway for wagons and motor trucks. Heavy bumping timbers are bolted along this side of the building, on a level with the floor, to protect the wall from damage by trucks. In each side wall there are doorways, 8 feet wide and 8 feet high, spaced 18 feet between centers and fitted with sliding doors. The door jambs are protected against damage in trucking by means of

cast-iron guards. To eliminate the necessity of *spotting cars,* or placing them opposite the doorways, the track side of the freight house may be composed entirely of sliding doors, forming panels between the posts which support the roof.

At the end of the building which fronts on the street are the entrance hall and foreman's office. A vehicle weighing machine or scale with a platform 9 feet by 22 feet is placed in the driveway, the scale beam and recording apparatus being inside the office of the foreman and under his care. The freight room is divided into two sections by a transverse fire-wall, which extends above the roof and has a doorway fitted on each side with a fireproof door that will close automatically in case the temperature rises above a certain point, as in a fire. A small over-freight room, in which freight held for orders or not accounted for may be stored, and a toilet room are located on opposite sides of the wall, as shown. As the freight house illustrated is for a division point, it has an upper story at one end, in which are located the division freight offices, a general office for the freight clerks, the freight agent's office, a cashier's office, and a record room. Two toilet rooms for men and women employes are also located in this story.

The floors in the toilet rooms are of cement. The remainder of the space on the first floor is covered with $1\frac{1}{4}'' \times 2\frac{1}{4}''$ maple flooring, laid on a subfloor of 2-inch plank. The subfloor is nailed to $2'' \times 4''$ sleepers, which are spaced 16 inches between centers and embedded in the sand fill between the foundation walls. The floor in the second story is of $\frac{7}{8}'' \times 2\frac{1}{4}''$ maple flooring laid on $2'' \times 8''$ ceiling joists spaced 18 inches apart. Wood blocks, asphalt blocks, and sheet asphalt on a concrete base are also used for the main floors of freight houses. Where the main freight room is over a basement, the floor is designed to support a load of 300 to 500 pounds per square foot. The office floor is designed for a load of 50 pounds per square foot; on account of the weight of filing cases, the record room is designed for a load of 150 pounds per square foot.

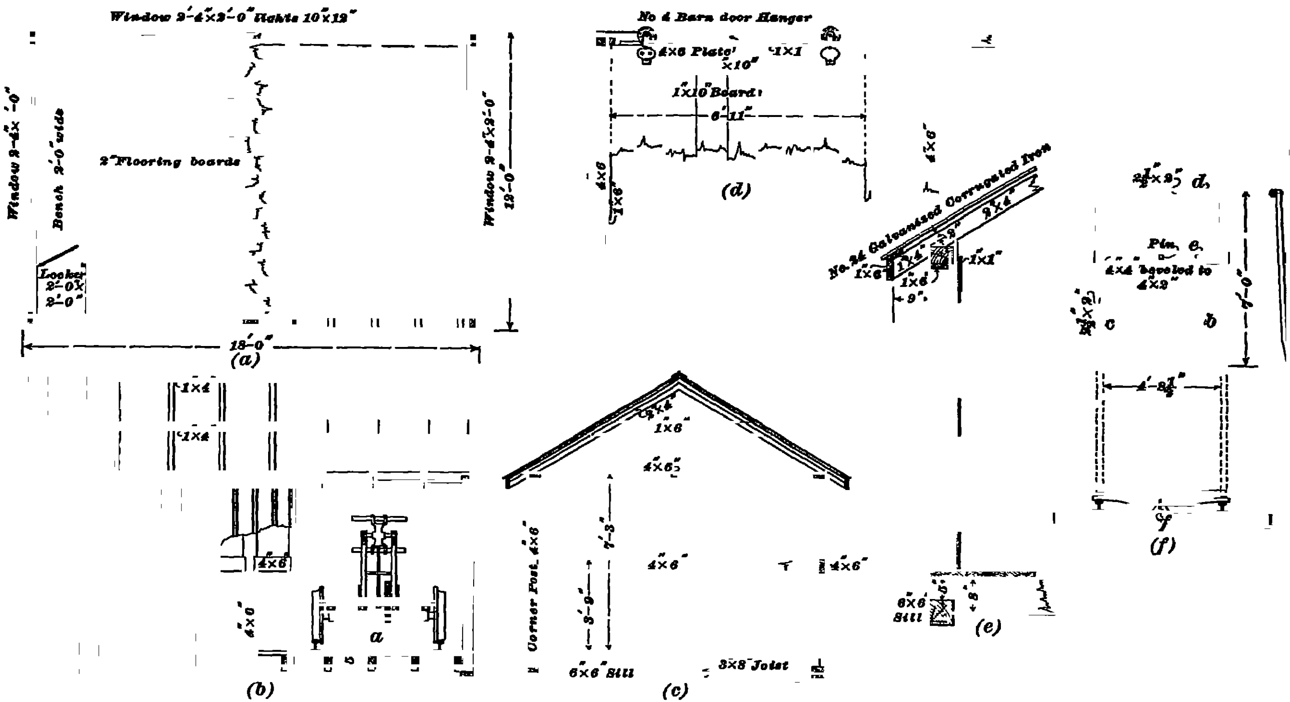
10. City Freight Houses.—Separate freight houses for inbound and outbound freight are required at large cities

Usually, outbound freight houses are 30 feet wide, while inbound freight houses are 50 feet wide; more room is required for the latter because inbound freight may have to remain some time before being called for, while outbound freight is loaded and shipped promptly Where the outbound freight business requires more than six tracks, the method of hand trucking along a side platform and through the cars, to reach the cars on the outer tracks, takes too much time; it is usually better to put the freight house across the ends of the tracks and to arrange the tracks in pairs with trucking platforms between them In case the tracks are a considerable distance above or below the street level, ample elevator service should be provided to handle freight between the vehicle platforms and the train platforms.

Freight houses in large cities are frequently built several stories high The ground floor is used for handling freight, while the remaining floors are either used by the railroad, or leased to others for warehouse purposes Where the storage business is sufficient to warrant it, provision should be made for cold storage In cities where the building laws prohibit the frame structures or at points where valuable freight is stored, some form of fireproof construction must be used.

MISCELLANEOUS BUILDINGS

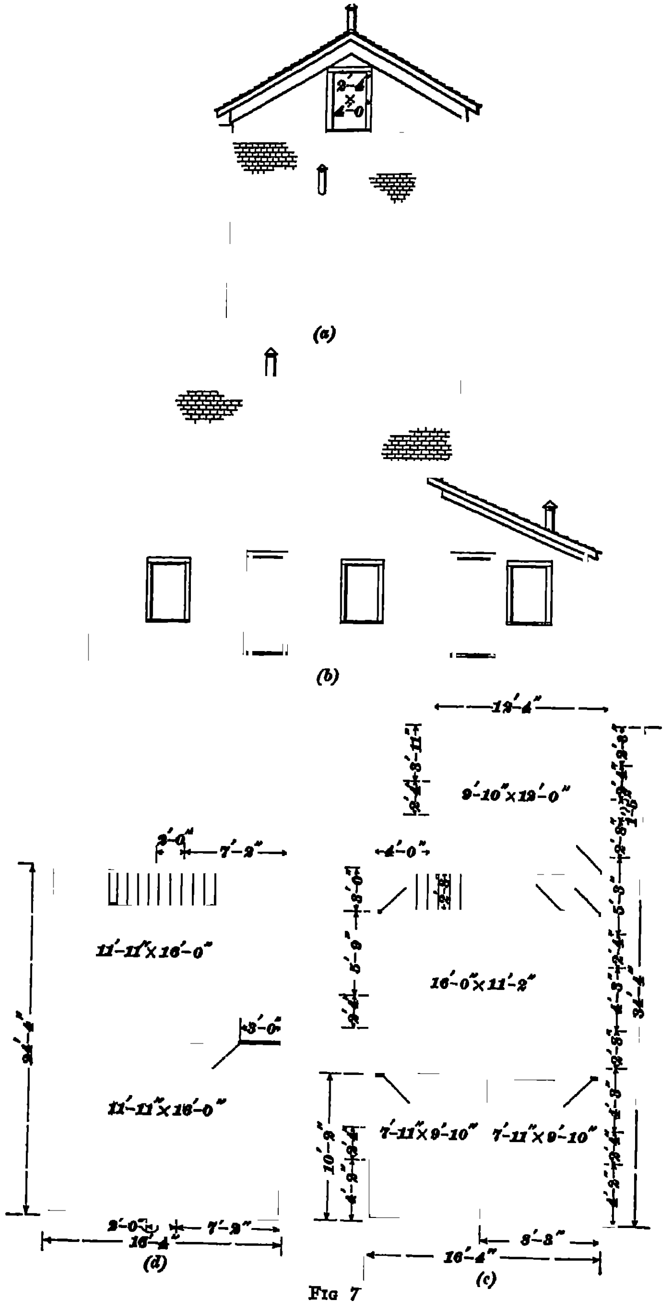
11. Section Tool Houses.—For the purpose of track maintenance every railway division is divided into sections, each in charge of a foreman and a gang of laborers. A small tool house is provided on every section to house the hand car or motor car, the push car, and the various tools and small track materials used by the section gang, in order to protect them from the weather and from being stolen. A light timber-frame construction is usually employed and the building rests on masonry piers or wooden foundation posts The building may be about 12 ft. × 18 ft. or 14 ft. × 20 ft with an 8-foot doorway in one of the long sides, equipped with a sliding door. A smaller type of building is 10 ft × 14 ft and has double swinging doors in one of the narrow sides


Window 2'-4"×2'-0" Lights 10"×12"
Window 2-4"× '-0"
Bench 2'-0" wide
Locker 2'-0"× 2'-0"
2" Flooring boards
Window 2-4"×2'-0"
12'-0"
18'-0"
(a)
1×4
1×4
4×6
4×6
a
(b)
No 4 Barn door Hanger
4×6 Plate
1×1
×10"
1"×10" Boards
6'-11"
4×6
1×6"
(d)
No 24 Galvanized Corrugated Iron
2"×4"
1"×4"
1×6"
1×6"
1×1"
9"
4×6"
2"×4"
1×6"
4×6
7'-3"
Corner Post 4"×6"
3'-9"
4"×6"
4×6"
6"×6" Sill
3×8" Joist
(c)
6"×6" Sill
8"
(e)
d
Pin e
4×4 beveled to 4×2"
c
b
7'-0"
4'-8½"
f
(f)
Fig 6

The building is placed with the door side facing the railroad track, and the section car is run into it on a short track Sufficient space to accommodate a section car must be left between the building and the main track. If the floor is of wood plank laid on joists, the building should be slightly above the ground in order to allow air circulation under the floor and so prevent decay of the wood Outside the building should be a clear space for piling large scrap iron, such as couplers and brake beams, that is picked up along the railroad Smaller scrap, such as bolts, spikes, etc, may be placed in shallow bins in the building, where the scrap is ready for periodical collection by a work train or supply train

12. Details of Tool House.—Details of a 12′×18′ section tool house are given in Fig 6. A plan is shown in (*a*), a side elevation and part section in (*b*), an end elevation in (*c*), and details in (*d*), (*e*), and (*f*) As illustrated in (*a*), at one end of the building is a work bench, fitted with a vise, and racks or shelves for the various tools used by the section gang A locker for lanterns and oil cans is fitted under the work bench in this case, but the locker is more likely to be kept clean if it is on a level with the bench.

The section car and push car rest on a track *a* in (*b*) They are admitted through a sliding door, shown in detail in (*d*), and in section in (*e*) A portable turntable for transferring the cars back and forth between the tool-house track and the main-line tracks is shown in (*f*) It consists of a frame built of two oak strips *b* and *c*, which serve as rails and are held to the proper gauge by the cross-piece *d* and the bolster *e*, bolted to the strips A pin passes through the bolster and enters a socket in the cast-iron pedestal *f*, on which the frame revolves In operation, the pedestal is placed on a tie with the strips *b* and *c* resting directly on the rails upon which the car that is to be transferred is standing The car is run onto the frame and the latter is revolved so as to connect the rails *b* and *c* with the rails of the track to which the car is being transferred.



(a)
(b)
12'-4"
9'-10"×12'-0"
2'-0"
7'-2"
4'-0"
11'-11"×16'-0"
16'-0"×11'-2"
3'-0"
11'-11"×16'-0"
7'-11"×9'-10"
7'-11"×9'-10"
10'-9"
34'-4"
2'-0"
7'-2"
16'-4"
8'-3"
16'-4"
(d)
(c)

Fig 7

The roof covering specified in (*e*) is corrugated iron Various kinds of prepared roofing or shingles are also employed

13. Section Dwelling House.—Where dwelling houses must be provided for the foremen and section gangs, they should be comfortable as well as of moderate cost Various designs are used by different railroads Details of a typical dwelling house are shown in Figs 7 and 8 Such a building may be built by ordinary carpenters It provides accommodations for eight persons A separate wing or separate building is sometimes provided for the foreman and his family.

In the design illustrated here, the outer walls and partitions consist of two courses of 1-inch boards nailed securely to the frame These boards are ship-lapped and surfaced on one side so as to take paint well The floor boards are of similar material and are tongued and grooved to make a tight fit The roof covering in this case is of corrugated iron, but various kinds of prepared roofing are also suitable for such buildings

In Fig 7 are shown an end elevation of the building in (*a*), a side elevation in (*b*), a plan of the first floor in (*c*), and a plan of the second floor in (*d*)

Complete framing details of the building are given in Fig 8. A framing plan of the second floor is shown in (*a*) and of the first floor in (*b*) In (*c*) is given a cross-section along plane *A-A*, which shows the arrangement of the floors and stairs A detail of the roof framing of the main body of the house is shown in (*d*), and of the roof of the addition in (*e*). In (*f*) is shown a detail of the sill and the floor joists, and in (*g*), a detail of a door casing.

14. Watchman's Shanty.—Shelter should be provided for watchmen at all road crossings and yards. The general design of a shanty for such purpose is shown in Fig 9. A watchman's shanty should be large enough to accommodate one man comfortably and provide room for a stove. Adjacent to the shanty should be a coal bin

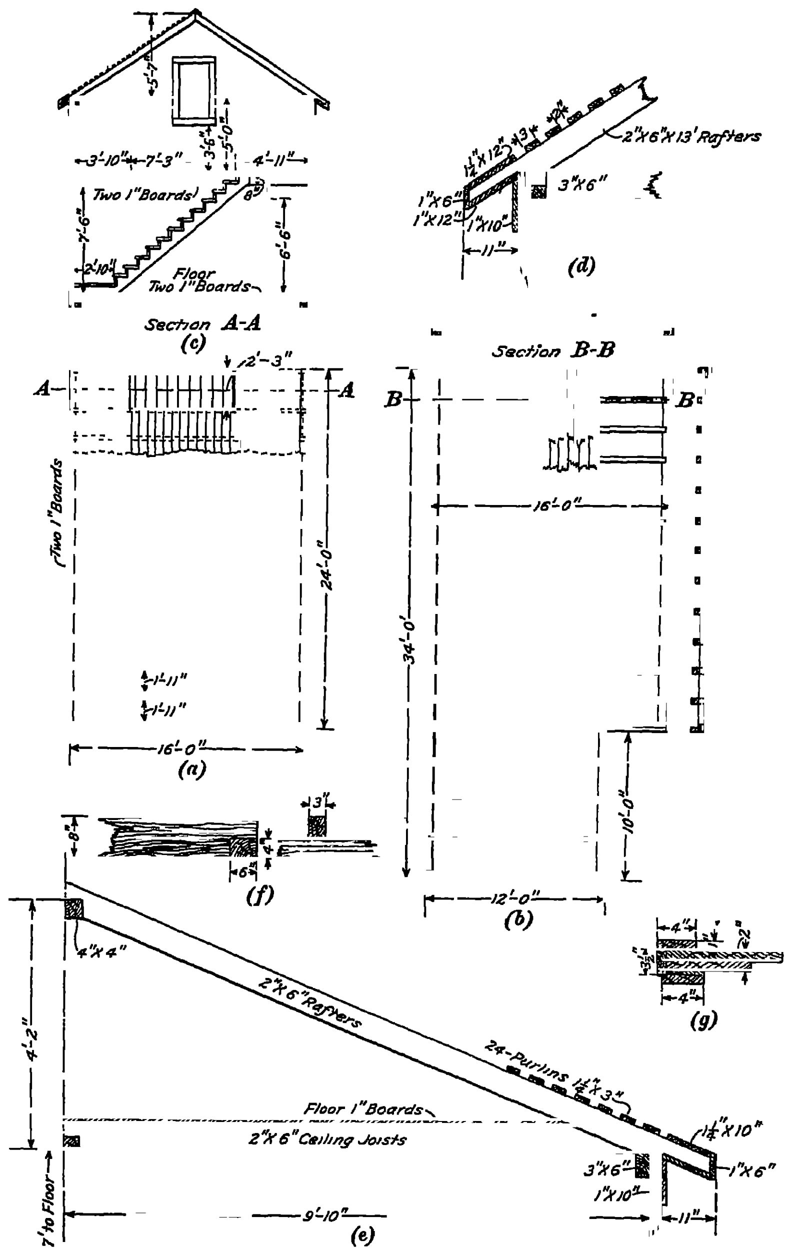

5'-7"
3'-10"
7'-3"
3'-6"
5'-0"
4'-11"
Two 1" Boards
8"
7'-6"
2'-10"
Floor
Two 1" Boards
6'-6"
Section A-A
(c)
1¼"x12"
1"x6"
1"x12"
1"x10"
11"
3"x6"
2"x6"x13' Rafters
(d)
Section B-B
2'-3"
A
A
Two 1" Boards
24'-0"
1'-11"
1'-11"
16'-0"
(a)
B
B
16'-0"
34'-0"
10'-0"
12'-0"
(b)
8"
3"
4"
6"
(f)
4"x4"
4'-2"
2"x6" Rafters
24-Purlins 1¼"x3"
Floor 1" Boards
2"x6" Ceiling Joists
1¼"x10"
3"x6"
1"x6"
1"x10"
7' to Floor
9'-10"
11"
(e)
4"
2"
4"
(g)

Fig 8

15. Live-Stock Pens.—On lines having a heavy traffic in live stock, pens are provided at certain points for loading and unloading the animals Since the law requires that live

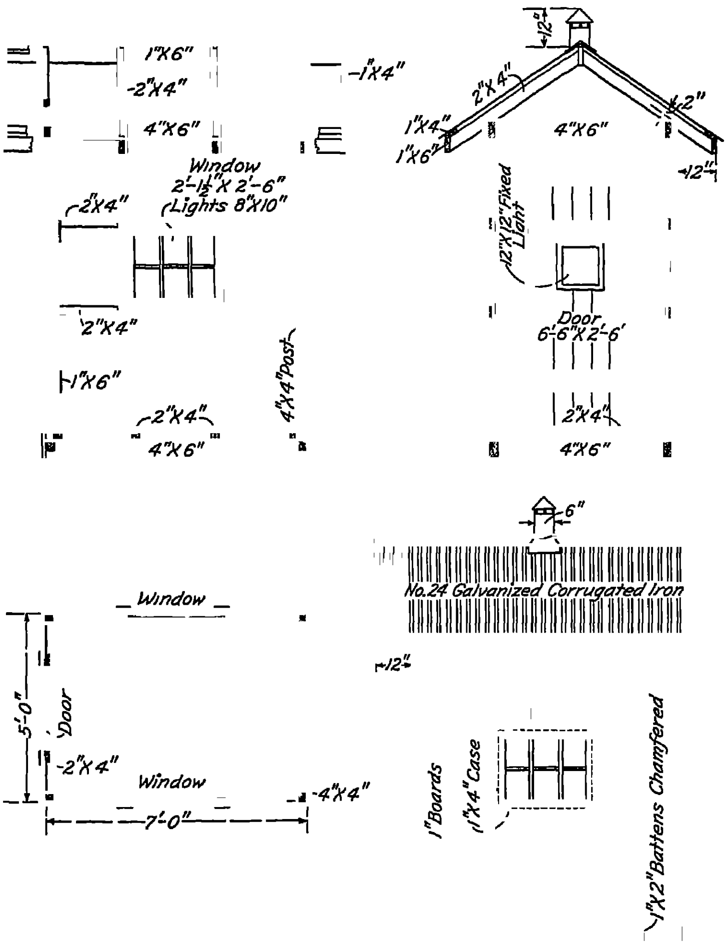


Fig 9

stock must not be kept in the cars for more than a specified number of hours, yards must also be provided along the line so that animals being transported a considerable dis-

tance can get exercise At many country stations, small pens are required in which farmers may place live stock waiting to be loaded A loading chute or runway, over which the animals are driven in loading or unloading, is required at all stations where live stock is handled.

16. Icing Platforms.—Where provision is made for refilling the ice tanks of refrigerator cars carrying fruit, vegetables, etc, a long icing platform is built with a track on one or each side This platform is constructed so as to be level with the tops of the cars Along the center of the

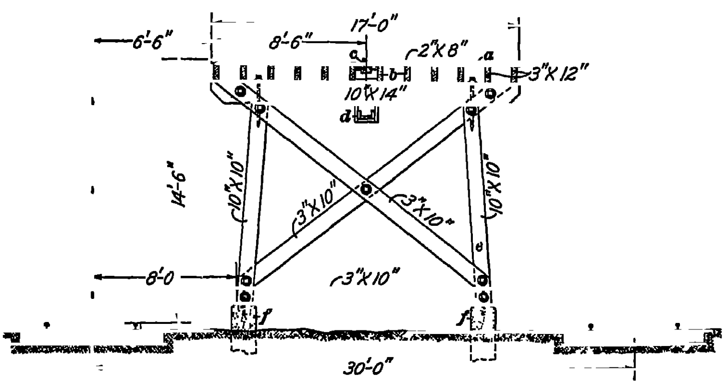


FIG 10

platform is an ice conveyor that carries the cakes of ice, from an adjacent ice house, along the platform Men with ice tongs pull the cakes of ice off the conveyor and slide them over hinged aprons or chutes to the roof hatches of the refrigerator cars Double-deck platforms are constructed where crushed ice and salt are handled for repacking cars carrying meat products The crushed ice is carried in wheeled carts or tubs along the upper deck of the platform and delivered to the cars through portable spouts

The icing platform shown in Fig 10 is constructed of 2″×8″ planks *a* spiked to 3″×12″ longitudinal joists *b* It has a center opening extending the full length of the platform for the accommodation of the ice conveyor *c* The trough *d* is for the return side of the conveyor The plat-

form is 17 feet wide and its top is 14 feet 6 inches above the top of the rails It is supported by timber bents *e* spaced 16 feet between centers. The posts of the bents rest on concrete piers *f*. This platform is built between two tracks and is long enough to serve a solid train of 40 cars on each track.

FENCES, CROSSINGS, AND SIGNS

RIGHT-OF-WAY FENCES AND RAILWAY CROSSINGS

RIGHT-OF-WAY FENCES

17. Types of Right-of-Way Fences.—The kind of fencing for railway right-of-way is specified by law in several states. The height required is usually not less than 4 feet 6 inches above the ground. Three types of fences in general use are *woven-wire fences, strand-wire fences*, and *board fences* Woven-wire fencing consists of longitudinal galvanized steel wires having vertical stay wires woven across them or welded to them Strand wire is obtainable in three shapes round, ribbon or twisted, and barbed

The posts for right-of-way fences are constructed of wood, concrete, or steel.

18. Wire Fences.—Right-of-way fences are usually of wire. The following four classes of wire fences are listed by the American Railway Engineering Association:

Class A is a woven-wire fence with nine longitudinal wires; the top and bottom wires to be of No 7 gauge, and the intermediate and stay wires of No 9 gauge. The spacing of the longitudinal wires, commencing at the bottom, should be 4, 4½, 5, 5½, 6, 7, 8, and 9 inches The stay wires should be spaced 12 inches apart This wire is hung with the bottom wire 5 inches above the ground, and may be made hog-tight by placing a strand of barbed wire 2½ inches below the woven wire.

Class B is a woven-wire fence with seven wires spaced 6½, 7, 7½, 8, 8½, and 9 inches apart, and stay wires 12 inches apart. All wires should be of No 9 gauge. This fencing is hung with the bottom wire 7 inches from the ground

Class C is a combination fence consisting of woven-wire fencing 25½ inches high with three strands of barbed wire above it The wires of the woven-wire fencing should be of No. 9 gauge and the stay wires should be spaced 12 inches apart The seven longitudinal wires should be spaced 3, 3½, 4, 4½, 5, and 5½ inches apart The spacing of the three strands of barbed wire above the woven wire should be 4½, 10, and 12 inches

Class D is a strand-wire fence consisting of five strands of round, ribbon, or barbed wire, the bottom wire being placed 10 inches above the ground and the others spaced 10, 10, 12, and 12 inches apart

19. Board Fences.—A board fence is usually constructed five boards high The fence boards are either 1 in $\times$ 4 in or 1 in $\times$ 6 in and 16 feet long They are spaced 5 to 6 inches apart and are nailed to wooden posts spaced 8 feet apart.

20. Fence Posts.—Wooden posts may be of catalpa, cedar, chestnut, larch, locust, oak, pine, or any durable wood that can be obtained locally In many cases such posts are either entirely treated with a preservative or have the lower portion dipped in some preservative Three kinds of posts are used in a fence, namely, line posts, which carry the fence wire, and corner and gate posts, which are heavier posts placed at corners and gateways Line posts are usually 4 or 5 inches in diameter at the top or small end, 7 to 8 feet long, and are set 2½ to 3 feet in the ground Corner and gate posts may be 7 or 8 inches in diameter at the top, 8 to 9 feet long, and set 3½ to 4 feet in the ground

Concrete fence posts are practical and economical and are extensively used They may be square, round, or half round in section, and reinforced with four or six steel bars Line posts vary from 3 in $\times$ 3 in at the top, tapering to 5 in $\times$ 5 in at the bottom, to 5 in. $\times$ 5 in at the top, tapering to 6 in $\times$ 6

in at the bottom The length runs from 6 feet 6 inches to 8 feet Concrete line posts are shown in Fig 11. Corner or gate posts are naturally heavier than line posts and are sometimes cast in place in one piece with a corner brace and footing, as shown in Fig 12 Fence wires are attached to the posts by means of lugs or hooks cast in the concrete or by tie-wires of the so-called Western Union twist, two types of which are shown in Fig. 11

Steel posts are in use to some extent. They are usually formed of tubes or **T** bars Ornamental iron fences are used around stations, yards, and shops.

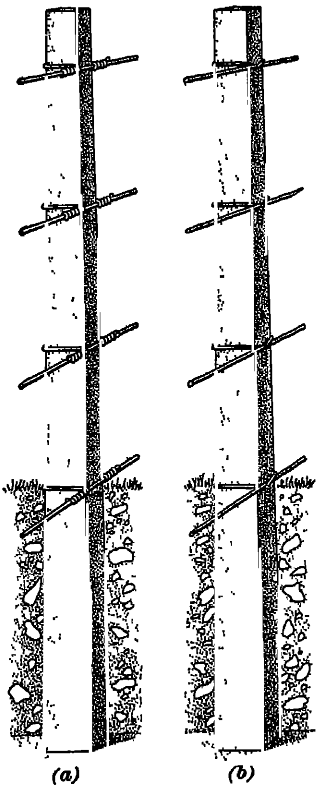


Fig 11

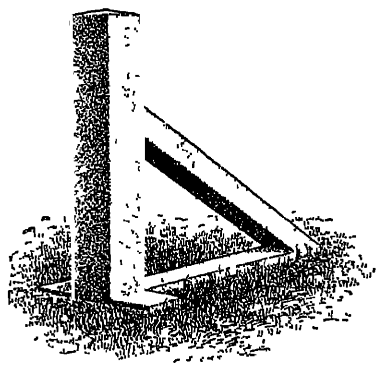


Fig 12

21. Construction of Wire Fences.—In setting the posts for a wire fence, a start may be made at a fence post set on the right-of-way line, the post having been located by measuring the offset distance from the center of the track as shown on a plan On curves, the offset distance for each post hole should be measured, but for a straight fence measurements may be taken at intervals of 100 to 200 feet and guide holes dug at these points. A chain or cord pro-

vided with tags for the proper spacing of posts is then stretched between these guide holes, and a man with a crowbar marks the positions for the intermediate holes. After the holes are dug the posts are placed and secured in position. The line posts for wire fences are spaced 16, 16½, or 20 feet apart; the posts of the braced panels at the ends, corners, or gates are spaced 8, 10, or 12 feet apart

22. Wire fencing is placed on the outer, or farm, side of the posts, except that on the inner side of a curve it is placed on the inner, or track, side so as to bear against the posts Before the wire is fastened to the posts, short braced panels are placed at gates, ends, and corners to hold

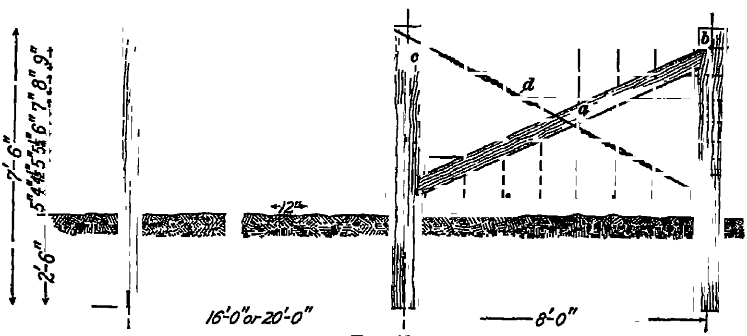


Fig 13

the fence in the proper position. In Fig 13 is shown an end panel constructed of wooden posts and Class A woven-wire fencing A diagonal wooden brace *a* is gained into the end post *b* near its top and into the adjacent line post *c* near the ground Three strands of heavy wire twisted together and looped around the posts *b* and *c* form the cross brace *d*.

When reinforced-concrete fence posts are used, a braced panel may be constructed by the method shown in Fig 14, where two reinforced-concrete struts *a* are fitted into recesses in the gate post *b* and line post *c*, and the whole is effectively tied together by the two wire cross-braces *d* In very long stretches of fence, braced panels should be introduced at intervals of a quarter of a mile.

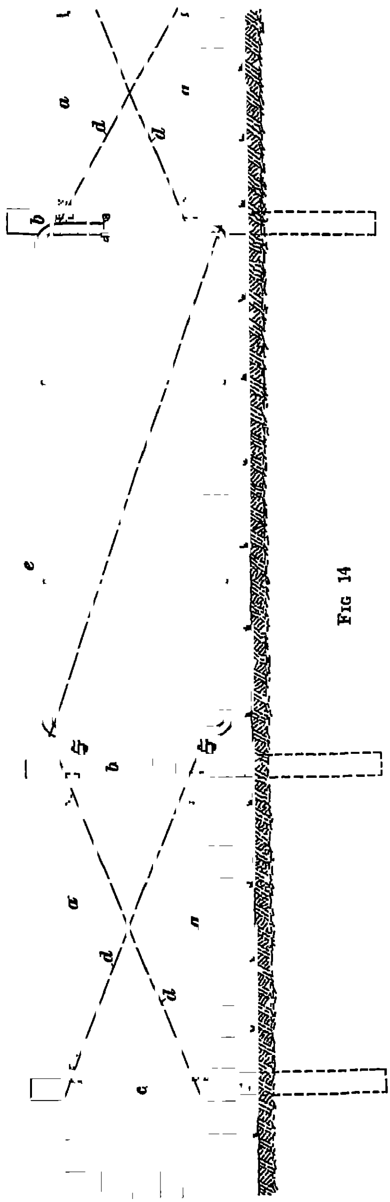


FIG 14

In the construction of a strand-wire fence, each wire should be strung separately, as otherwise the wires are likely to get tangled, unless the ground surface is very regular The wire is strung by fastening one end to the first, or starting, post, and the coil, or reel, on which the wire is rolled, is then carried forwards on a wheelbarrow or on a crowbar held by two men, the wire unwinding as it is taken forwards.

23. Fence Gates.—At farm crossings, gates must be provided to allow the live stock and farm vehicles to pass across the track Farm gates are constructed either of boards or of a steel frame covered with woven wire They should be hung so as to open away from the track, and if hinged, as is desirable, should close by gravity The gate may be long enough to overlap the gate post so that it cannot be forced open toward the track A steel-frame gate that meets these requirements is shown in Fig. 14 at *e*.

24. Wing and Apron Fences.—Since the railway owns no part of the public roads, the right-of-way fences

at grade crossings are turned in toward the track and placed parallel with the road, forming what are known as wing fences, as in Fig 15 Sufficient clearance must be left between the ends of the wing fences *a* to permit trains to pass with-

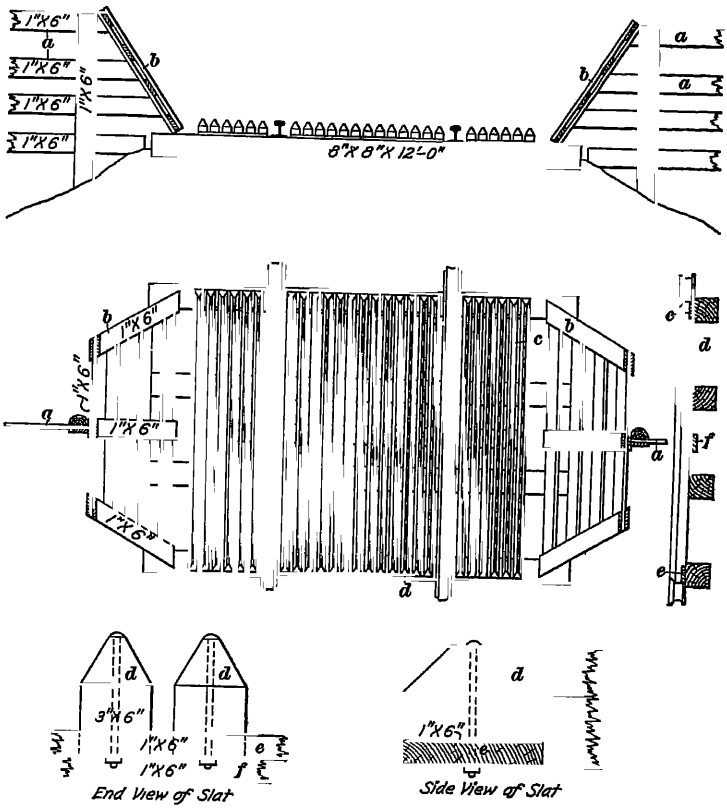


Fig 15

out danger of striking the fence This clearance distance is usually 12 to 18 feet for a single-track line Wing fences are placed on both sides of the crossing and on both sides of the track Lying against the end of each wing fence, is a single-panel apron fence *b*, laid parallel with the track If the clearance is only 12 feet, the apron fence slopes away from the track so as to be clear of the cars

and trainmen riding on the sides of the cars, for 18 feet clearance the apron fence may be vertical The space between the wing fence and apron fence is covered with the device c, called a *stock-guard* or *cattle-guard*, which will be described in the next article Wing and apron fences and stock-guards may also be placed at farm crossings that are much used

RAILWAY CROSSINGS

25. Stock-Guards.—At grade crossings of public roads some device must be placed which will prevent live stock from wandering along the track but will not interfere with the passage of trains Formerly a pit or trench was dug across the track and lined with timber or masonry walls carrying stringers on which the rails were laid A modified plan was to lay ties across the stringers, the sides of the ties being beveled so that they offered no foothold However, pit guards are dangerous, because the timbers are liable to be burned by hot cinders falling from locomotives, and animals may get trapped in the pit and cause train wrecks

It is now almost universal practice to have the ordinary ballasted roadbed and track continuous at crossings, but to place on the ties a surface stock-guard, formed of some kind of slats 6 to 8 feet long which offer no foothold and are too long to be jumped The surface stock-guard shown at *c* in Fig 15 is composed of 3″×6″ wooden slats *d*, the sides of which are beveled for 2 inches below the top They are spaced 2 inches apart and are bolted to two 1″×6″ cross-pieces *e* resting on the ties A cross-piece *f* is spiked under the middle of the slats Metal stock-guards are usually constructed of flat bars, tee bars, or angle bars attached to metal cross-pieces.

26. Road Crossings.—Where the railway crosses roads and streets, the paving between rails must be so constructed as to provide flangeways or grooves for the passage of the wheel flanges and also to permit access to the track for maintenance and repair. Four types of road crossings are

shown in Fig 16 In (*a*) wooden planks are laid parallel with the rails and spiked to the ties, filler pieces being placed on the ties to bring the planks level with the top of the rails. The outside planks are laid close to the rails but the inner planks are laid 2¼ inches away to form flangeways. Old rails are laid against the inner planks to protect the edges from wear The method illustrated in (*b*) is the same as that in (*a*), except that steel angles are used to protect

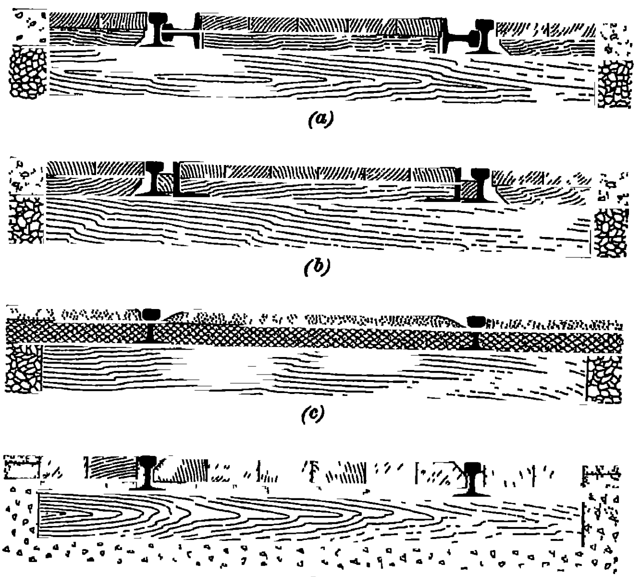


Fig 16

the inner planks, wood fillers are placed between these angles and the webs of the rails

In (*c*) is shown a comparatively new method, which consists of paving the entire crossing with cold bituminous macadam already prepared After the track has been well surfaced a layer of ballast stone, previously mixed with about ½ gallon of bituminous composition per cubic foot of stone, is laid and tamped to a finished thickness of about 2½ inches Upon this course is laid a similar layer of ballast

stone, $\frac{1}{4}$ to 1 inch in size, mixed with $\frac{3}{4}$ gallon of composition per cubic foot of stone After this has been tamped and the flangeways formed, a coat of bituminous composition is flushed over the entire surface and covered with fine stone chips Another modern method, used to a considerable extent, is to pave the crossing with broad concrete slabs or narrower concrete planks, which are spiked to the ties

In the method shown in (*d*), for crossings of asphalt-paved streets, a sand cushion, 1 inch to 2 inches thick, is laid on the cross-ties, and wood paving blocks are placed on the sand cushion. The joints between the blocks are filled with asphalt and a wearing course of asphalt is sometimes placed over the entire crossing.

SNOW FENCES AND SHEDS

SNOW FENCES

27. Permanent Snow Fences.—To protect cuts from drifting snow, fences built of boards may be erected along the windward side of the railway cut The snow fence checks

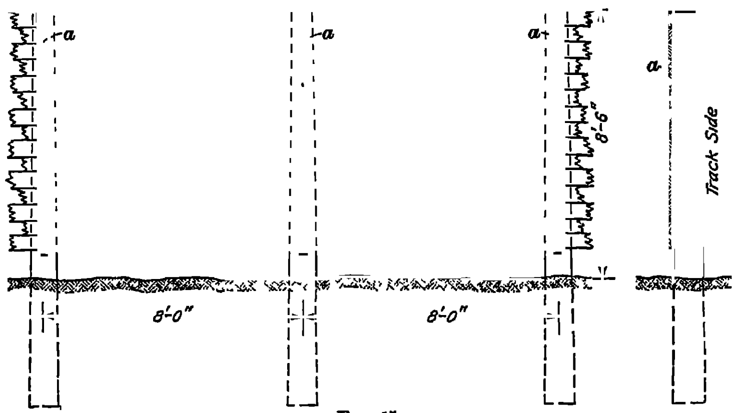


FIG 17

the sweep of the windblown snow and causes the snow to be deposited along the fence instead of being carried into the cut and blocking traffic The location of the snow fence

depends upon such local conditions as the topography of the ground, prevailing winter winds, amount of snowfall, etc Where local conditions permit, a permanent snow fence located on the railway right-of-way is most economical A type of permanent snow fence recommended by the American Railway Engineering Association is shown in Fig. 17. This fence is 8 feet 6 inches high and is constructed of 1-inch boards, 16 feet long and of any width, nailed to wooden fence posts spaced 8 feet apart Battens *a* are nailed to the boards at every post.

28. Portable Snow Fence.—If the right-of-way is narrow, a permanent snow fence cannot be used, as it would be too close to the cut to give the desired protection In

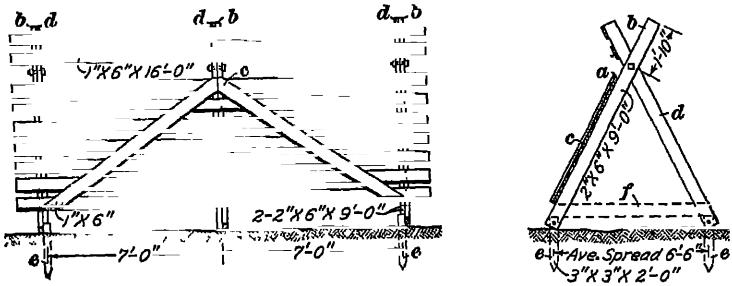


FIG. 18

this case, a portable snow fence may be placed on private property adjoining the cut, a small rental being paid for permission to occupy the land These fences are made in separate folding panels so that they can be folded up and removed in the spring when farming operations begin In Fig 18 is illustrated one panel of a portable snow fence recommended by the American Railway Engineering Association The panel is constructed of 1″×6″ boards *a*, 16 feet long, spiked to three posts, and braced by the 1″×6″ boards *c*; each post is made of two 2″×6″ planks *b* and *d*, bolted together near the top so that they can be spread to form **A**-shaped supports When not in use, the two planks are folded together so that the panels can be stacked flat These panels are held in

position by the small guy stakes *e* driven into the ground. When guy stakes cannot be used, as in rocky soil, cross-boards *f* are nailed on the frames and old ties or rocks are loaded onto planks laid on these cross boards, so as to hold the fence panels in place

SNOW SHEDS

29. Use of Snow Sheds.—In mountainous districts subject to heavy snowfall or avalanches of snow which are often accompanied by rocks and earth, the track is sometimes protected for long distances by snow sheds built over it Snow sheds are also used to some extent on level ground where the snowfall is excessive. Two typical snow sheds are illustrated in Fig 19.

30. Timber Snow Sheds.—A snow shed usually consists of heavy timber bents, placed 4 to 10 feet apart, connected by longitudinal bracing, and with the sides and roof formed of planks. In order to provide ventilation, the sides are left open for a distance of about 2 feet below the eaves Since the passage of a train through such a shed is almost as objectionable as through a tunnel, some roads have what is called a *summer track* This is a track outside the shed, for use when there is no snow. A timber snow shed suitable for flat country is shown in Fig 19 (*a*).

31. Concrete and Timber Construction.—Concrete and a combination of concrete and timber are used to a great extent in the construction of snow sheds A combination concrete and timber snow shed for a double-track road in mountainous country is shown in Fig. 19 (*b*) In this case the space behind the concrete retaining wall is filled with rock and earth, which eliminates the large amount of timbering necessary to carry the roof back to the natural slope of the ground.

32. Fire Protection.—In long stretches of timber construction the danger from fire is considerable and the sheds are often equipped with pipes supplying water from an elevated tank. To prevent the spread of fire, the shed is sometimes

broken by open spaces about 100 feet long These open stretches of track may be protected by V-shaped fences or

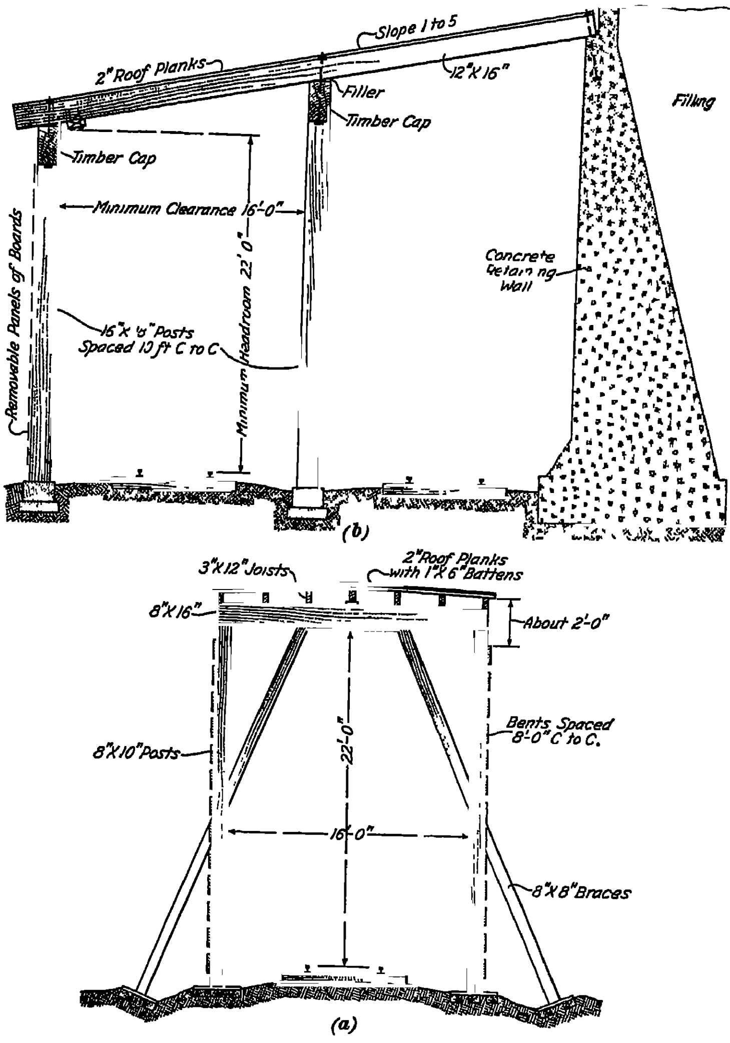


Fig 19

deflectors on the hillside above the railway In level country, movable sections 100 feet long, traveling on wheels, are some-

times provided at intervals in long snowsheds, and in case of fire these sections are removed, thus preventing the fire from running the full length of the shed

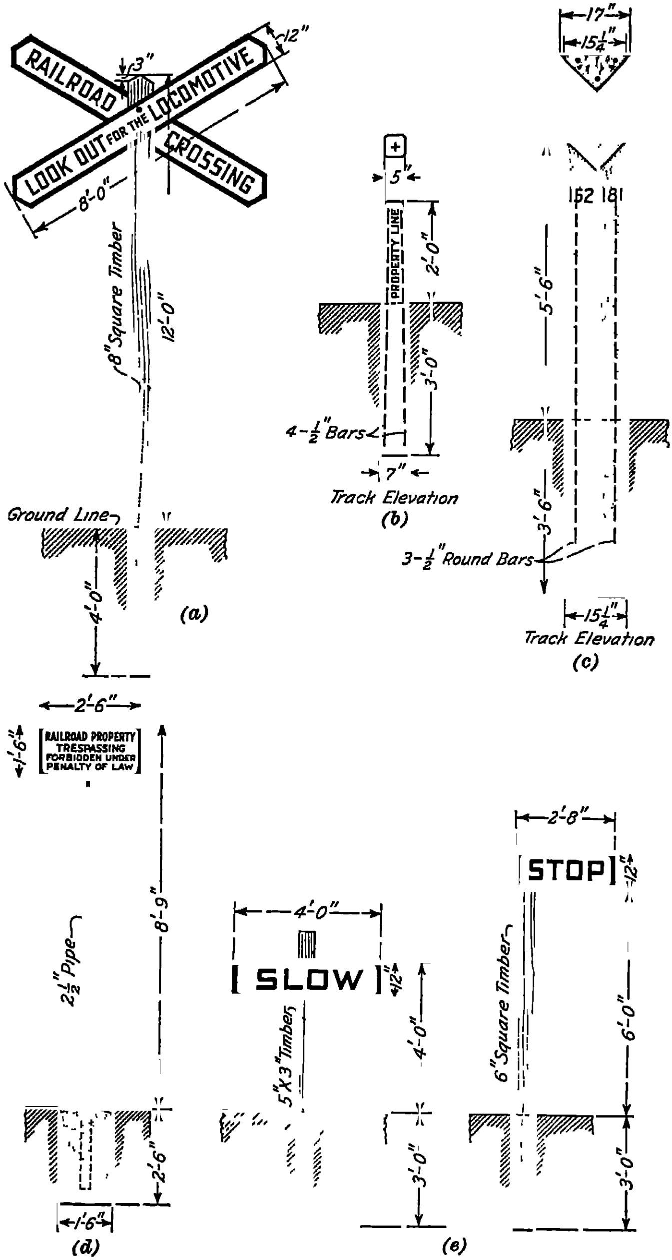
SIGNS AND BUMPING POSTS

33. Signs.—Various marking and warning signs are required along a railway for the guidance of trackmen, enginemen, brakemen, and the public, to indicate distances, special points, danger points, highway crossings, etc Signs should be strong and durable, simple in design, economical in construction, conspicuous, and easily recognized

In Fig 20 are shown some of the various signs used by railways In (*a*) is a highway crossing sign, erected to warn the public to look out for trains. The blades are painted white with black letters and a ½-inch black border. In (*b*) is a reinforced-concrete property post; it is used to mark the railway property line, or right-of-way line; similar posts may be set opposite the P C. and P. T. of all curves and at every 1,000 feet on tangents for checking the alinement of the track. The exact location of the point through which the line passes is indicated by a cross cut in the top of the post In (*c*) is a concrete mile post, the numbers 181 and 152 mean that one terminal station is 181 miles to the right of the post and another is 152 miles to the left of the post The trespass or warning sign shown in (*d*) is to warn people to keep off the railway's property The *slow* and *stop* signs shown in (*e*) are used at the approaches to track crossings, drawbridges, etc

In Fig 21 is shown a bridge tell-tale or tickler, which is placed on each side of a tunnel or a low bridge to warn brakemen on the top of cars that they must stoop or lie down.

34. Bumping Posts.—The ends of tracks in yards and stations, on elevated lines, at docks, etc, should be equipped with some sort of bumper or bumping post to prevent cars from running off. There are several different types of bumping posts in use and they are constructed of wood, steel, or concrete, or combinations of these materials.



RAILROAD
CROSSING
LOOK OUT FOR THE LOCOMOTIVE
12"
3"
8'-0"
8" Square Timber
12'-0"
Ground Line
4'-0"
(a)
PROPERTY LINE
5"
2'-0"
3'-0"
4-½" Bars
7"
Track Elevation
(b)
17"
15¼"
162 181
5'-6"
3'-6"
3-½" Round Bars
15¼"
Track Elevation
(c)
2'-6"
1'-6"
RAILROAD PROPERTY
TRESPASSING
FORBIDDEN UNDER
PENALTY OF LAW
8'-9"
2½" Pipe
2'-6"
1'-6"
(d)
4'-0"
SLOW
12"
5"X3" Timber
4'-0"
3'-0"
2'-8"
STOP
12"
6" Square Timber
6'-0"
3'-0"
(e)

FIG 20

A typical wooden bumping post is shown in Fig 22, in side elevation in (*a*) and end elevation in (*b*) This device consists of two vertical posts *a*, mounted on the frame work *b*, and

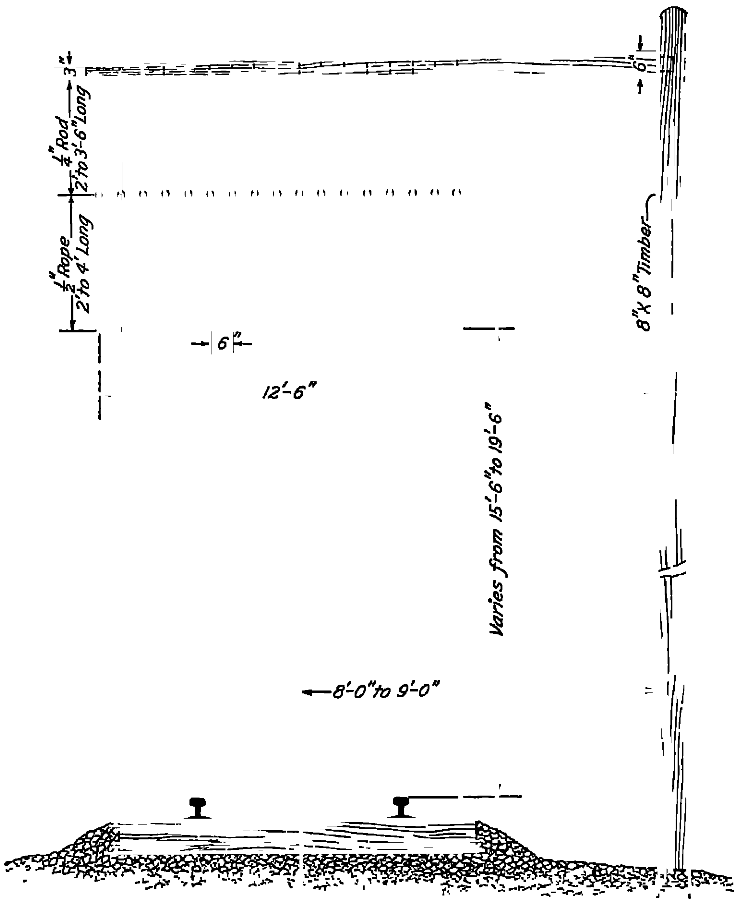
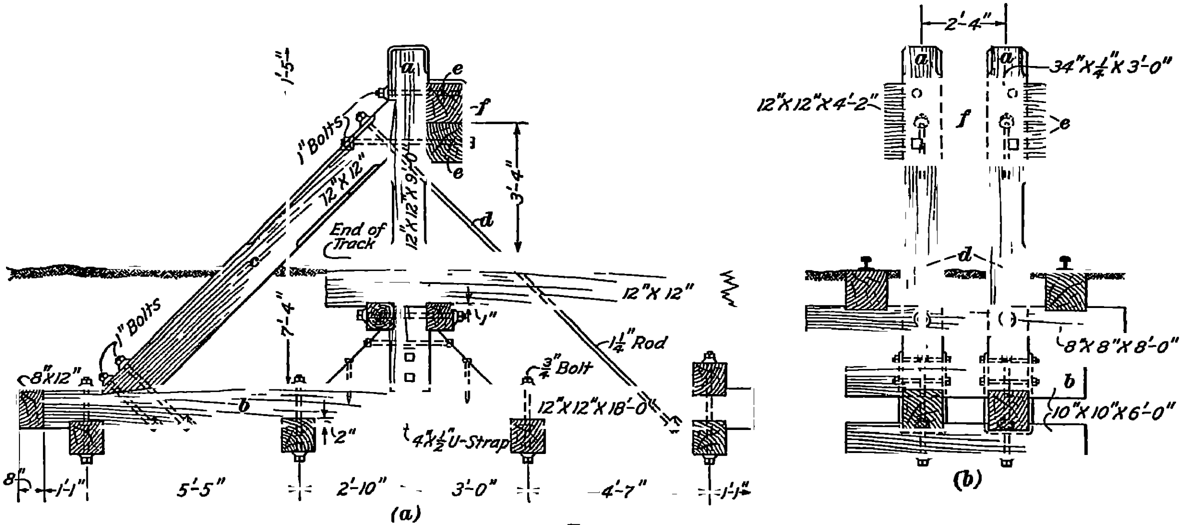


FIG 21

effectively braced by two back braces *c* and two tie-rods *d* At the top the vertical posts carry heavy cross-timbers *e*, which are faced with the steel bumping plate *f*.



a
e
f
e
1" Bolts
12"X 12"
12"X12"X 9'-0"
End of Track
d
3'-4"
1'-5"
1" Bolts
8"X12"
7'-4"
b
2"
1"
12"X 12"
1¼" Rod
¾" Bolt
12"X12"X18'-0"
4"X½" U-Strap
8"
1'-1"
5'-5"
2'-10"
3'-0"
4'-7"
1'-1"
(a)
2'-4"
a
a
34"X¼"X3'-0"
12"X12"X4'-2"
f
e
d
8"X8"X8'-0"
b
10"X10"X6'-0"
(b)

FIG. 22

YARDS AND TERMINALS

FREIGHT YARDS

DESIGN AND LAYOUT OF YARDS

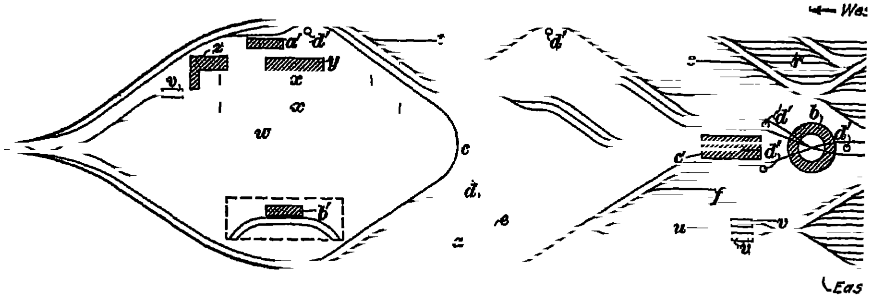
35. Purpose of Freight Yards.—An outbound or outgoing freight train made up at any terminal or division yard consists of cars for various destinations and with varied classes of freight At the next junction or division point, therefore, the inbound or arriving train must be *broken up;* that is, the cars must be separated or classified for different destinations or for different kinds of commodities. Cars for transfer to local industries, or those that are to be forwarded over branches and connecting railroads, must be separated from cars to be sent further on over the main line At large terminals, cars may have to be distributed to freight houses, warehouses, factories, coal and ore docks or piers, grain elevators, etc

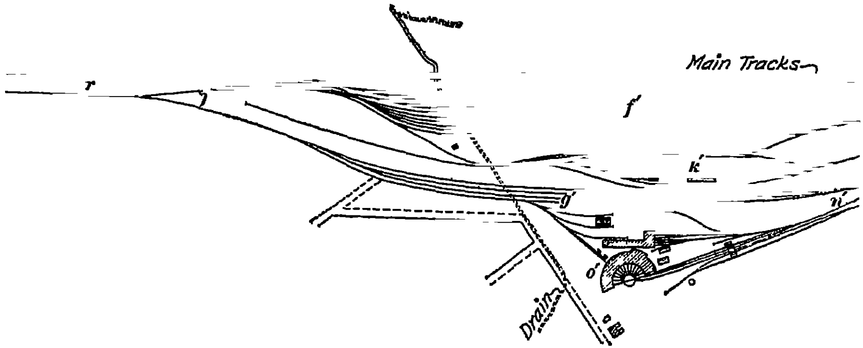
A freight yard, consisting of an extensive and well-designed system of tracks, is required for the complicated work of breaking up inbound or arriving trains and making up or assembling outbound trains, in order that such work may proceed rapidly, efficiently, and economically The freight yard, however, must not be regarded as an independent machine for shifting and storing cars It must be recognized as simply one factor in the general work of railway transportation or operation Its highest efficiency will be reached when cars are delayed as little as possible and when the work is done at a minimum cost, mere rapidity of movement of cars in a yard, however, may not mean economy, as it may be done at the expense of damage to cars and freight The aim should be for general speed in yard operations, with due regard to ultimate efficiency.

36. Yard Design.—No standard design of a yard is feasible owing to varying local and traffic conditions, nor is it practicable to have the ideal yard layout at any point, since topography and property boundaries are likely to influence the design. This is specially true of yards in and near large cities, and, hence, there is a growing tendency to locate yards in the open country where land sufficient for a desirable layout can be obtained at a relatively low cost

The yard itself is made up of a series of connected groups of tracks, the parallel or body tracks of each group being connected at one or both ends by a diagonal or ladder track Certain fundamental features must be included in any freight-yard design Thus, provision is required for taking inbound trains from the main track before they reach the yard, so that if a train cannot be admitted to the yard immediately it will stand on a side track or yard lead instead of blocking the main track Receiving tracks are required where the inbound trains stand while the cars are inspected and marked for destination Next will be the classification tracks, where cars for the same destination or cars with the same kind of commodities are placed together On some of these tracks or on separate advance or departure tracks, outbound trains are made up for the trip over the next division These departure tracks should be equipped with compressed-air piping, so that the air brakes can be tested when the train is ready but the locomotive has not yet been coupled on. A group of repair tracks is needed, where cars can be repaired, and also a bad-order track, on which cars requiring repairs can be set ready for removal to the repair tracks At least one thoroughfare or through track is required in a freight yard, which is to be kept open at all times to allow movements all the way through the yard. In determining the lengths of the various tracks in a yard, it is customary to allow 42 feet per car for all tracks except repair tracks, 50 feet per car being required for the latter to provide working space at the ends of cars

37. Yard Layout.—A theoretical yard layout is shown in Fig. 23 (*a*), each track being represented by a single line





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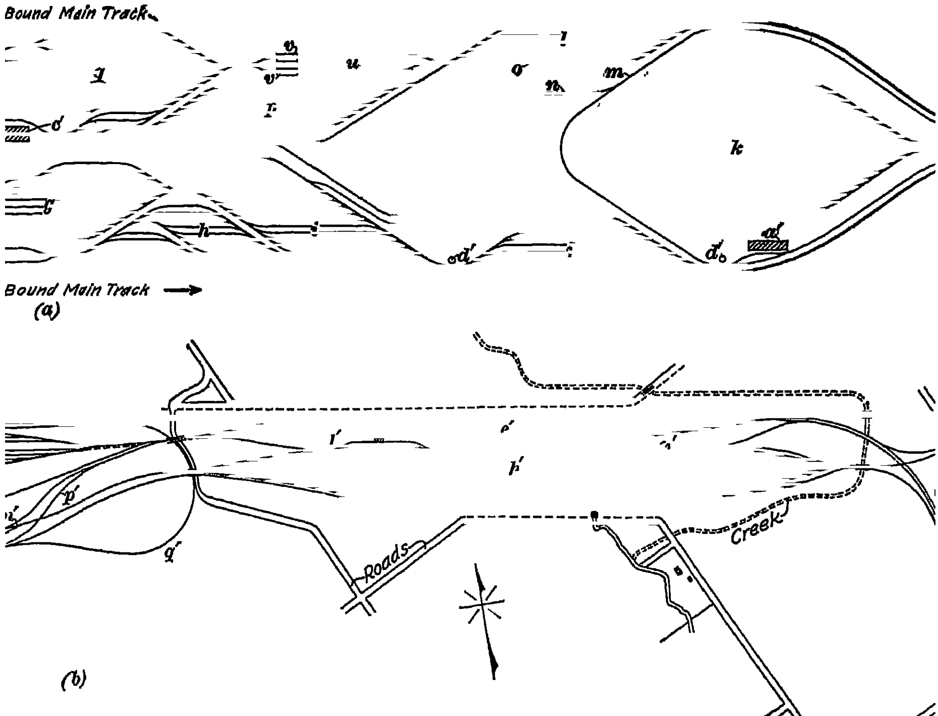


FIG 23

In practice, the longitudinal arrangement of the groups of tracks in series is sometimes modified by topographical features, property boundaries, and other conditions The separate groups may have to be arranged more or less side by side, thus forming a yard of shorter length but greater width The main line tracks may pass along one side of the yard, or may be separated to include the yard between them The yard is divided into two divisions for traffic in opposite directions.

Beginning at the left end of Fig. 23 (*a*), eastbound trains from the main line tracks are diverted onto the receiving tracks *a*; here the locomotive is cut off or detached and sent to the roundhouse *b* The caboose also is cut off and shifted to the caboose track *c*, convenient for attaching it to an outbound or westbound train. If repairs are necessary, the caboose is shifted to the caboose-repair track *d*. While on the receiving tracks, each car is inspected and marked for destination; two or more consecutive cars for the same destination may be handled together as a unit or *cut of cars* The cars found defective are switched onto the bad-order track *e* for later removal to the repair tracks *f* If a car needs extensive repairs, its load may have to be transferred to another car Cars that have passed inspection and have been marked for their destination are then placed on the proper classification tracks *g* in groups as required for making up trains; cars for local orders are accommodated on the local-order tracks *h* Outbound trains for the east are made up on the advance tracks *i*. Cars for fast-freight trains, which must be forwarded without delay, are placed on the group of fast-freight tracks shown at *j*, while cars that are not to leave promptly are placed on the hold or storage tracks *k*.

Beginning at the right end of Fig. 23 (*a*), westbound trains are diverted from the main line onto the receiving tracks *l*, where the locomotive is detached and sent to the roundhouse *b*; the caboose is shifted to the caboose track *m*, and if necessary to the caboose-repair track *n*. Defective cars are shifted to the bad-order track *o* and later removed to the repair tracks *p* The two sets of car-repair tracks, *f* for eastbound

trains and *p* for westbound trains, are seldom used in practice; one set of car-repair tracks usually serves the entire yard Cars that have been inspected and marked for destination are placed on the classification tracks *q*, and cars for local orders are shifted to the local-order tracks *r* Outbound trains for the west are made up on the advance tracks *s* Cars for fast-freight trains are made up on the fast-freight tracks *t*.

In each group of poling tracks *u*, the function of which will be explained later, two tracks are shown provided with track scales *v*. The arrangement shown is rarely used, there being generally only one scale for eastbound and one for westbound cars. The tracks *w* are local-freight and team-yard tracks, and the transfer platforms *x* are for transferring freight from lightly loaded cars to make full carloads One of these platforms adjoins the freight station *y*, near which are the cattle pen *z* and the ice house *a′* Another ice house *a′* is at the other end of the yard Near the local-freight tracks is located the trainmen's building *b′*. Among the various structures in the yard are the coaling stations *c′* and the water columns *d′*.

In Fig 23 (*b*) is shown a layout of an actual freight yard and engine terminal similar to that of the Michigan Central Railroad at Niles, Michigan. The westbound receiving and classification tracks are shown respectively at *e′* and *f′*, while the eastbound receiving and classification tracks are respectively at *g′* and *h′* The caboose track *i′* is located near the westbound receiving tracks and the caboose track *j′* is near the eastbound receiving tracks The repair tracks *k′* are used for both westbound and eastbound cars, light repairs for eastbound cars being made on the light-repair tracks *l′* Engines from eastbound trains can move from the eastbound receiving tracks onto the lead track *m′* and from there get on the track *n′* that leads to the roundhouse *o′* From the westbound receiving tracks, engines can get to the roundhouse by means of the track *p′* The semicircular loop track *q′* passes under the tracks in its path, and thus allows outgoing westbound engines to get to the departure tracks *r′* without interfering with the movement of eastbound trains.

38. Yard Switches.—The body tracks of each group of tracks are spaced about 13 feet between centers and connect at each end with a ladder track The two ladder tracks may be in the same direction, as in the receiving tracks *a*, repair tracks *f*, etc , of Fig 23 (*a*), or they may be in opposite directions as in the fast-freight tracks *j* and the local-order tracks *h* In the former case all the body tracks will be of the same length, while in the latter case the length will vary In yard work, No 7 frogs are often used, but the modern tendency is to use nothing less than No 8, with No 10 frogs for connections to running tracks and main-line tracks

Convenience and safety require that the main-line tracks be kept entirely separate from the yard tracks It will be noticed in Fig. 23 (*a*) that the only connection between the main tracks that surround the yard and the yard tracks is by the series of switches at the extreme ends of the yard Even at small yards and stations, all yard and side tracks and all spur tracks to industrial plants should run out from a side track or lead track connected to the main track by a single switch Such switches should be amply protected by signals Large yards usually have interlocking switch and signal plants at the connections to the main tracks

39. City Yards.—In large cities, local yards are provided at different points for the loading and unloading of cars that are moved to and from the main terminal yards, where trains are broken up and made up Such a yard will usually have a team yard as previously described Since these local yards are usually located on expensive property where enlargement is prohibitive, they must be laid out to utilize the space to best advantage, even if sharp curves and small frogs are required. In this connection it is well to note that single cars can be moved over curves of 50 to 75 feet radius, but a minimum radius of 150 feet is necessary when coupled cars are to be handled.

SWITCHING

40. Flat Switching.—In an ordinary level yard, switching for classification purposes may be done by one of several methods One method is by means of a switch engine, which pulls the train backwards and forwards along the tracks, successive cars or cuts of cars are uncoupled from the rear end of the train, at each push or forward motion of the train, so as to run by their own momentum down the ladder track and onto the body track for which they are assigned In another method the engine pulls out each car or cut separately and then pushes it quickly to the ladder track, thus giving it sufficient momentum to run to the desired point These methods are slow and expensive, especially in large yards An improved method is to have an engine running back and forth on a poling track, situated as shown at *u* in Fig 23 (*a*). Each car or cut is uncoupled and pushed forwards by means of a horizontal pole, pivoted to the side of the engine or to a car attached to the engine, until it has attained sufficient speed to run onto its proper body track Poling may be assisted materially by giving the ladder track a descending grade of about ½ per cent, and extending this grade into the body tracks In all these methods a brakeman usually rides the car that is being switched in order to stop it at the proper position and to avoid its striking heavy blows against other cars standing on the tracks.

41. Gravity Switching.—Gravity switching is now extensively used in large yards owing to the rapidity, facility, and economy in working In this method, an incline of such grade is built that a car started down the incline gains sufficient speed to run onto the classification tracks A brakeman rides the car to stop it, and in large yards an adjacent track is provided for a motor car that returns the brakemen promptly to the starting point The topography will sometimes enable this incline to be formed as a drop in grade all the way from the receiving yard to the classification yard As a rule, however, an artificial hill, called a *hump*, is required This hump

has a long easy approach grade of 1 or 1½ per cent ascending to its summit A yard engine pushes the train slowly up the approach grade of the hump to the summit, at which point the cars are uncoupled, one or more at a time, and allowed to descend by gravity down the hump to their desired destination In very large yards of this type the switches of the classification track may be operated by electric or pneumatic apparatus controlled from a cabin, located on a bridge over the summit of the hump

The actual profile of the hump for any yard must be adapted to the local conditions of traffic and climate. Loaded cars roll easier than empty ones and all cars roll easier in warm weather than in cold weather The grades that can be used will vary, therefore, according to whether the cars are mainly loaded or empty When there are extremes of summer and winter temperatures the grades are sometimes varied from time to time by increasing or decreasing the depth of ballast.

42. Making Up Trains.—To prepare an outbound train, cars are pulled successively from diffierent classification tracks and pushed together on one departure track Where there are no separate departure tracks, the trains are made up on some of the classification tracks The cars are coupled automatically as they come in contact A yard crew connects the brake hose and other pipes and inspects the journal-boxes for lubrication When all the cars are in place the brakes are tested With a caboose and a locomotive attached the train is ready to start on its run

ENGINE TERMINALS

43. Care of Locomotives.—Each division of a railway system has its own locomotive equipment A locomotive takes its train over the division and is then detached at the station or freight yard, after which it must be made ready for a return trip The locomotive needs to be inspected, to have light or running repairs made, and to have its fire cleaned,

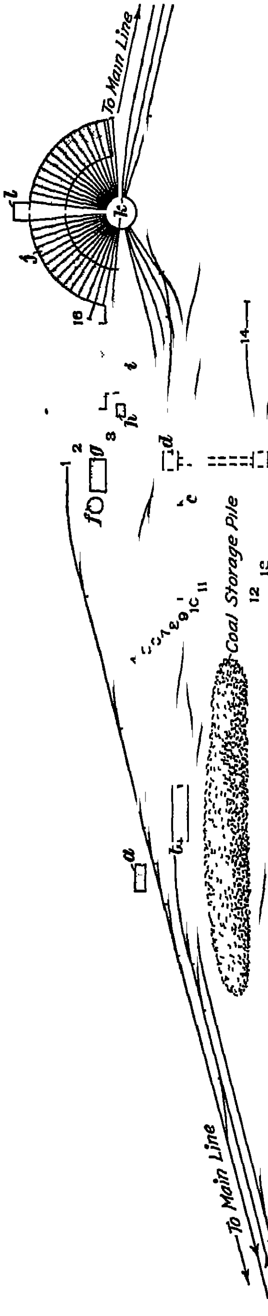


Fig 24

the machinery must also be cleaned and lubricated, and the tender must be supplied with fuel and water. At times it will also be necessary to wash out the boiler in order to remove the dirt and scale. Provision for thus taking care of the locomotive is made at an engine terminal, which is located at the middle of a long freight yard, as in Fig 23 (*a*), or more generally adjacent to the freight yard, as in (*b*)

After being inspected, cleaned, fueled, and watered, a locomotive that is to make a return trip promptly may be placed on a locomotive storage track, located outdoors in the engine terminal If the locomotive is to be repaired or is not required to make a return trip at once, it must be placed in the roundhouse until needed A locomotive in the roundhouse is usually dead, that is, its fire is out, and the fire must be kindled in sufficient time for the locomotive to start on its run

44. Arrangement of Terminal Facilities.—The principal elements of an engine terminal are the inspection pits, the ash-pits, fuel and water stations, turntable, and roundhouse

In the plan of a typical engine terminal, shown in Fig 24, *a* is a two-story building for the accommodation of the train dis-

patcher and the train crews; *b*, the shed-covered inspection pits, *c*, the ash-pits, *d*, coaling station; *e*, track hopper for coal; *f*, elevated tank, *g*, the power house; *h*, an oil house; *i*, a machine shop and platform; *j*, a roundhouse with thirty stalls for locomotives; *k*, a turntable, and *l*, a house for the boiler-washing plant and ventilating fans. In this terminal the various tracks are assigned as listed below:

1 Wrecking-crane track
2 Supply track to power house and machine shop.
3 Locomotive-repair track
4, 5, 6, and 7 Locomotive-storage tracks
8 and 9. Principal entrance tracks.
10 Ash-car track
11 Run-around track
12 and 13 Coal-supply tracks
14 and 15 Coal-car storage tracks.
16 Storage tracks for wheels

The coal-supply tracks are usually located close to the coaling station, but the arrangement shown here is to provide space for a large storage pile of coal alongside the tracks.

45. Application of Terminal Facilities.—In the plan of Fig. 24, a locomotive after being detached from its train enters the terminal on track 8 or 9 It first passes to the inspection pits *b*, which allow the men to get under it, and is thoroughly inspected It then passes to the ash-pits *c* to have the ashes dumped and the fire cleaned or drawn; then it moves on to take coal and water at *d*. The locomotive is next run onto the turntable *k* and set in position either to run on one of the locomotive-storage tracks or into the roundhouse *j*, depending on whether it is to make a return trip at once or is to be stored or repaired.

YARD AND TERMINAL STRUCTURES

ENGINE HOUSES

46. Types of Engine Houses.—A building called an engine house is provided at each division and terminal point in a railway system Here the locomotives are housed, cleaned, repaired, and made ready for the next trip Engine houses are of two types; namely, rectangular engine houses and roundhouses, the latter being generally used Rectangular houses may be provided either with parallel stub tracks having switches at one end only or with parallel through tracks connected at each end with a diagonal ladder track

47. Construction of Roundhouse.—A roundhouse is a building with curved walls, forming two parallel arcs of circles, and provided with from four to fifty or more radial tracks These tracks are served by a device for turning the locomotives called a turntable, whose pivot is at the center from which the radial tracks and the curves of the walls are drawn The angle between the center lines of the roundhouse tracks should be some even divisor of 180°, so that tracks at opposite ends of the turntable will simultaneously line up with the track of the turntable. To provide working space at each end of the locomotive, the width or depth of the building should be at least fifteen feet greater than the overall length of the largest locomotive and tender on the division Heavy timber framing with brick walls is generally employed, but concrete also is largely used. Steel framing is used only where special care is taken to eliminate smoke, because otherwise the metal corrodes rapidly To avoid interruption to traffic due to fire, it is often considered best to employ fireproof construction, such as reinforced-concrete roof and framing with brick walls. Additional security may be obtained by dividing the roundhouse into units of about 10 tracks, or stalls, by means of walls of fireproof material

The wall of the building facing the turntable is composed mainly of the entrance doors and the posts between them

on which the doors are hung and which support the roof The entrance doorways are usually about 13 feet wide, not less than 16 feet high, and are fitted either with wooden swinging doors or steel rolling doors. The outer or rear wall should have a large area of windows. A monitor roof, that is, a raised roof having side openings fitted with windows, will improve the light and ventilation Roof ventilators may also be used to help carry off the smoke and gases from the locomotives. Over each track or stall is placed a smokejack consisting of a large tapering hood, supported from the roof by hangers, with a flue or chimney passing through the roof The hood of the smokejack should reach within a few inches of the top of the locomotive smokestack and should be of sufficient length to provide for slight variations in the position of the locomotive on the track Smokejacks are made of metal or various special compositions In many cases they are merely of wood, covered with a fireproof paint, as they soon become coated with a protective covering of soot Between the rails of each stall is a concrete pit 50 to 60 feet long and about 3 feet deep to enable workmen to inspect, clean, and repair machinery An annex to the roundhouse frequently accommodates a small machine shop for repair work and a heater for a boiler-washing plant.

48. Typical Roundhouse.—In Fig 25 is shown a twenty-stall roundhouse, 92 feet wide, with concrete repair pits Instead of having a monitor roof, one part of the roof of this roundhouse is higher than the other; the vertical face thus formed is fitted with windows, as shown in the longitudinal section in (*a*) Six lines of wooden posts or columns support the roof framing, which consists of wooden beams and girders arranged as indicated in the framing plan (*b*) for one stall Knee braces stiffen the framing in both directions, and hangers and cross-pieces are provided to support the overhead piping systems. A ground-floor plan of one stall is illustrated in (*c*), and in (*d*) is shown a layout of the roundhouse, turntables, etc.

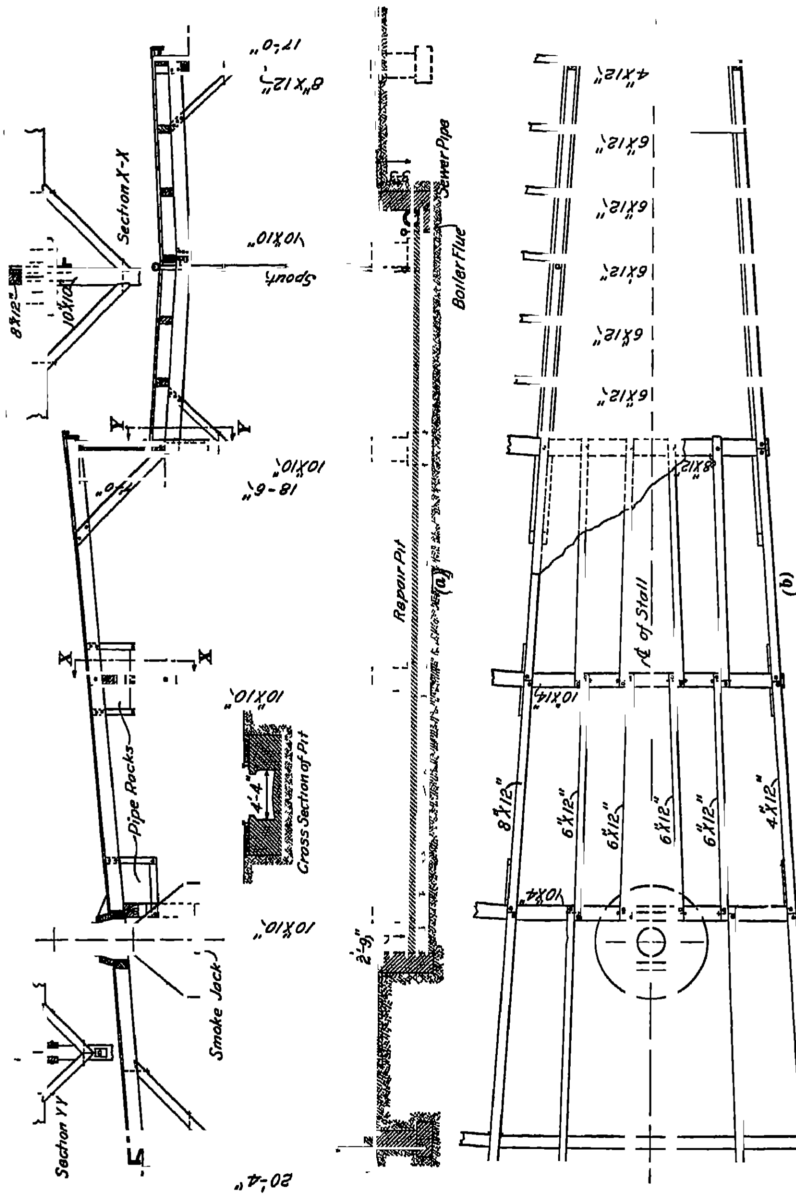
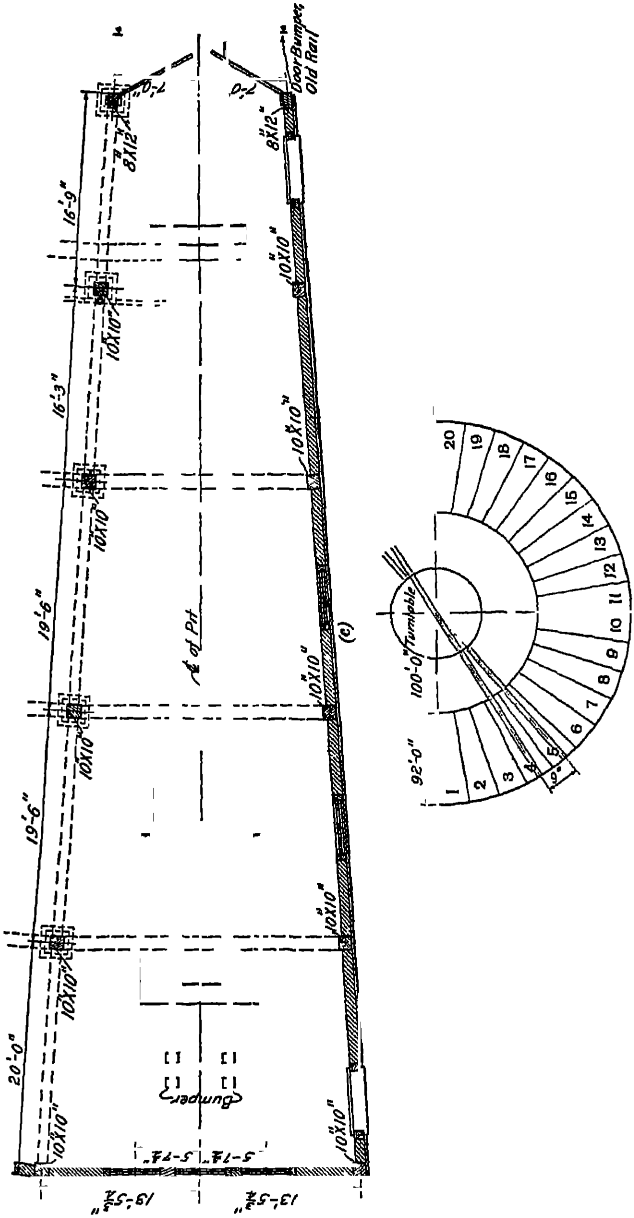

Section X-X
Section YY
Spout
Pipe Racks
Smoke Jack
Cross Section of Pit
4'-4"
Repair Pit
Boiler Flue
Sewer Pipe
2'-9"
℄ of Stall
17'-0"
18'-6"
20'-4"
10"x10"
8"x12"
6"x12"
4"x12"
10"x14"
(a)
(b)

Fig 25


20'-0"
19'-6"
19'-6"
16'-3"
16'-9"
7'-0"
7'-0"
8"X12"
8"X12"
10"X10"
Door Bumper
Old Rail
℄ of Pit
Bumper
5'-7¼"
5'-7¼"
13'-5¾"
13'-5¾"
100'-0" Turntable
92'-0"
9°
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

(c) (d)

Fig. 25

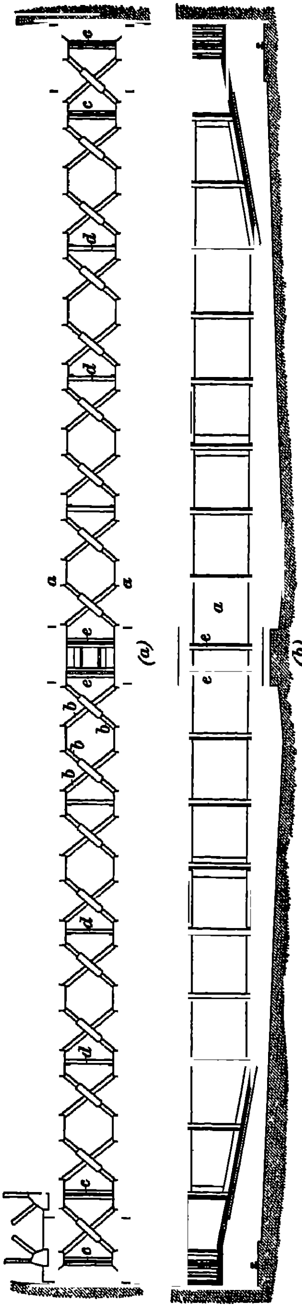


Fig. 26

49. Turntables.—To reverse the locomotives for their return trips and also to shift them to and from the radial tracks of the roundhouse, a device called a turntable is employed A turntable consists of a pair of girders braced together, carrying a single track, and revolving in a circular paved pit, as shown in Fig 26 In most cases these are deck girders, with track ties laid across them, in cases where the use of deck girders would necessitate very deep pits, they are either half-through girders, with ties carried between them by shelf angles on the girder webs, or through girders with the ties supported on the inside of the bottom flanges These latter two arrangements permit of deeper and stiffer turntables without excessive depth of pit. The length of a turntable is from 70 to 100 feet, depending on the overall length of the largest locomotive and tender to be handled The larger turntables usually have a central bearing or pivot and also a rim bearing at each end furnished by wheels running on a circular track The wheels prevent the table from tilting too far as a locomotive moves on or off, and also carry part of the load For such a design the table should be a little longer than the locomotive so that the locomotive may be moved to the proper position for balancing A small turntable may be supported entirely at the center In the most modern designs no balancing is necessary and the table need be only a little longer than the wheelbase of the engine and tender

If only a few locomotives are handled daily, the turntable has long wooden levers projecting from each end so that it can be turned by men pushing against these levers Where many locomotives are turned in a day, power operation is generally used, because of economy in time and expense. A one-wheeled tractor is coupled to one corner of the table and rides on the circular rail This tractor is driven by an electric, gasoline, or compressed-air motor and in turn operates the table

50. The steelwork for a typical deck-girder turntable is shown in Fig 26, in plan view in (*a*) and side elevation in (*b*)

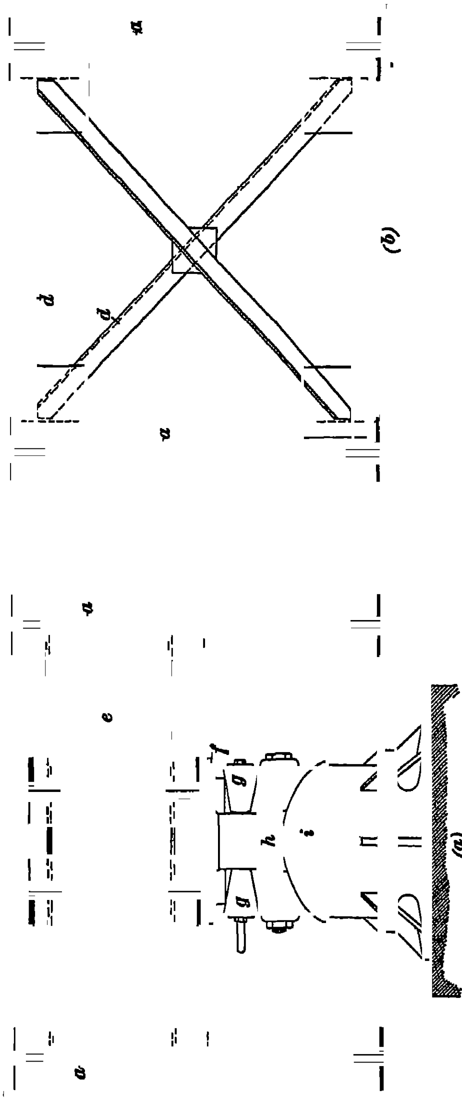


Fig 27

The two plate girders *a* are connected together at the top by means of the bracing members *b*, at each end by two transverse plate frames *c*, and at intermediate points by the cross-frames *d* Near the center of the structure are two cross-girders *e*.

In Fig 27 are shown cross-sections through the turntable, the one shown in (*a*) being taken near the center of the structure, and the one in (*b*) near the cross-frame *d*. As shown in (*a*), to the under side of the cross-girders is riveted the bearing plate *f* that rests on the ring of conical rollers *g* These rollers ride on the bearing plate *h* of the pedestal *i*, which is supported by and anchored to a concrete pier

Typical details of an end of the turntable are shown in Fig 28, an end view of the turntable being shown in (*a*) and an elevation of the end of a girder in (*b*). Each end of the turntable rests on two 2-wheeled trucks *j*, one truck being provided at the end of each girder The trucks ride on the circular rail *k* Across the girders are laid the ties *l*, in (*a*), that carry the track rails *m*, guard-rails *n*, and guard timbers *o* Long timbers *p* are laid at intervals across the girders to carry a footwalk *q* and railing *r* The floor of the pit is paved and generally dished so that water will run to the center drain

51. Transfer Tables.—At repair shops and car shops having a number of parallel transverse tracks, a traveling transfer table is used to shift a locomotive or car from one track to another. This table, shown in plan view in Fig. 29, consists of a platform *a*, carrying a single track *b*, long enough to hold the largest locomotive and tender operating in the division. The table is mounted on several pairs of wheels that ride on rails *c* in a shallow pit 15 to 24 inches deep, at right angles to the tracks of the shop or engine house. Some large rectangular engine houses, having parallel tracks, are served by transfer tables instead of by track connections and switches

The operation of a transfer table can best be explained by referring to Fig 29 Suppose a locomotive standing on track *1* is to be transferred to track *7*. The transfer table

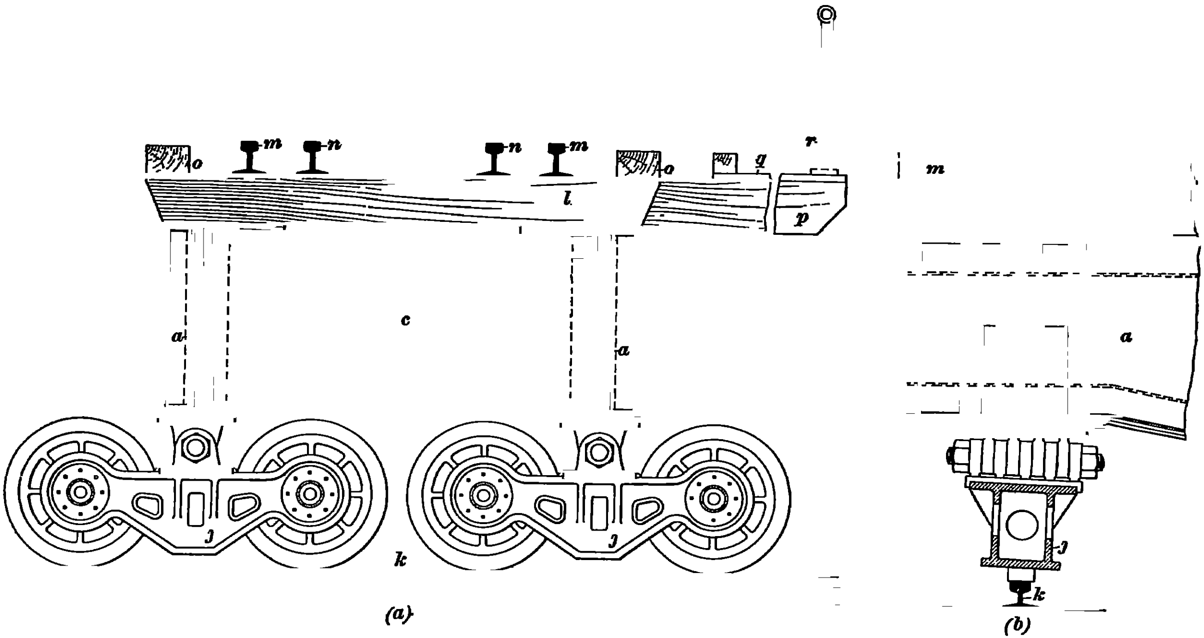


FIG 23

is run to the position shown in full lines where its track is directly in line with track *1*; the locomotive is then moved forwards onto the table and the table is run to the left, until

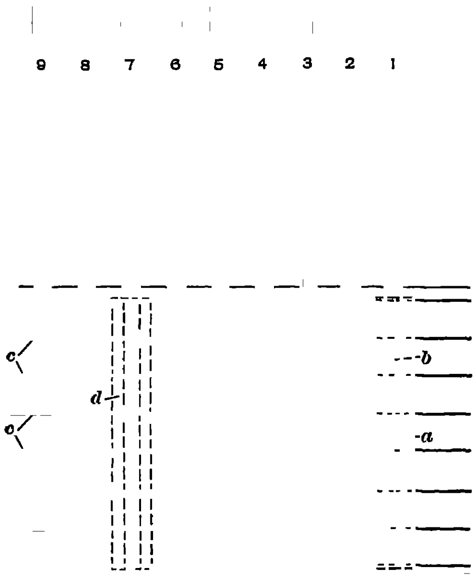


FIG 29

it is opposite track *7*, as shown in dotted lines at *d*. The locomotive can now be moved off the table onto track *7* Transfer tables are usually driven by electric or gasoline power.

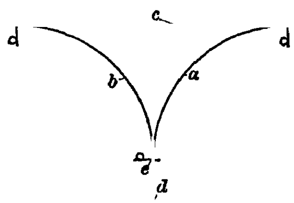


FIG 30

52. Y Track.—At points where locomotives are turned only occasionally, and also at rectangular engine houses where no turntables are provided, a **Y** track will serve for turning locomotives. As shown in Fig 30, a **Y** track consists of two

curves *a* and *b* running in opposite directions from a straight track *c* and uniting in a short stub-track *d*, which forms the stem of the **Y** A locomotive entering one curve from track *c*, runs down that curve onto the stub *d*; the switch *e* is then shifted and the locomotive runs out on the other curve to track *c* It is now facing in the opposite direction from which it entered the **Y.**

WATER SERVICE

53. Water Stations.—The tender tanks of locomotives need to be replenished with water during their runs and for this purpose water stations are provided at terminals, passenger stations, coaling plants, engine terminals, and intermediate points along the line The average distance between water stations is from 15 to 30 miles Their location is determined by the number of locomotives operating, the capacity of the tender tanks, and the sources of water supply, it is also determined by the profile of the line, since it would be undesirable to stop heavy trains on a steep grade or at the foot of such a grade in order to take water Tender tanks hold from 6,000 to 15,000 gallons of water and a locomotive evaporates 20 to 150 gallons of water per mile, depending on the weight of the train, steepness of grades, and various other factors

54. Sources of Water Supply.—The least expensive and most satisfactory water supply is that obtained from either springs or brooks that have sufficient elevation to deliver water into the supply tank by gravity and so avoid the expense of pumping Water may also be obtained from wells, rivers, lakes, or city-supply systems When the supply in times of drought is likely to run short, a reservoir is sometimes constructed to store surplus water for future use Water from streams needs to be passed through screens to remove leaves and floating trash Clear, pure water, as free as possible from mineral matter in solution, is greatly to be desired

55. Water Softening.—Water often contains matter which, under the influence of heat, is deposited in the form

of a hard scale on the boiler tubes, or a soft sludge or mud in the boiler The former is the more serious, since it retards the transmission of heat to the water, with consequent increased expenses for fuel, for cleaning out the boilers, and for boiler repairs For these reasons, it is becoming the general practice to bring good water from a distance or to use a water-softening system in order to remove or neutralize the scale-forming elements.

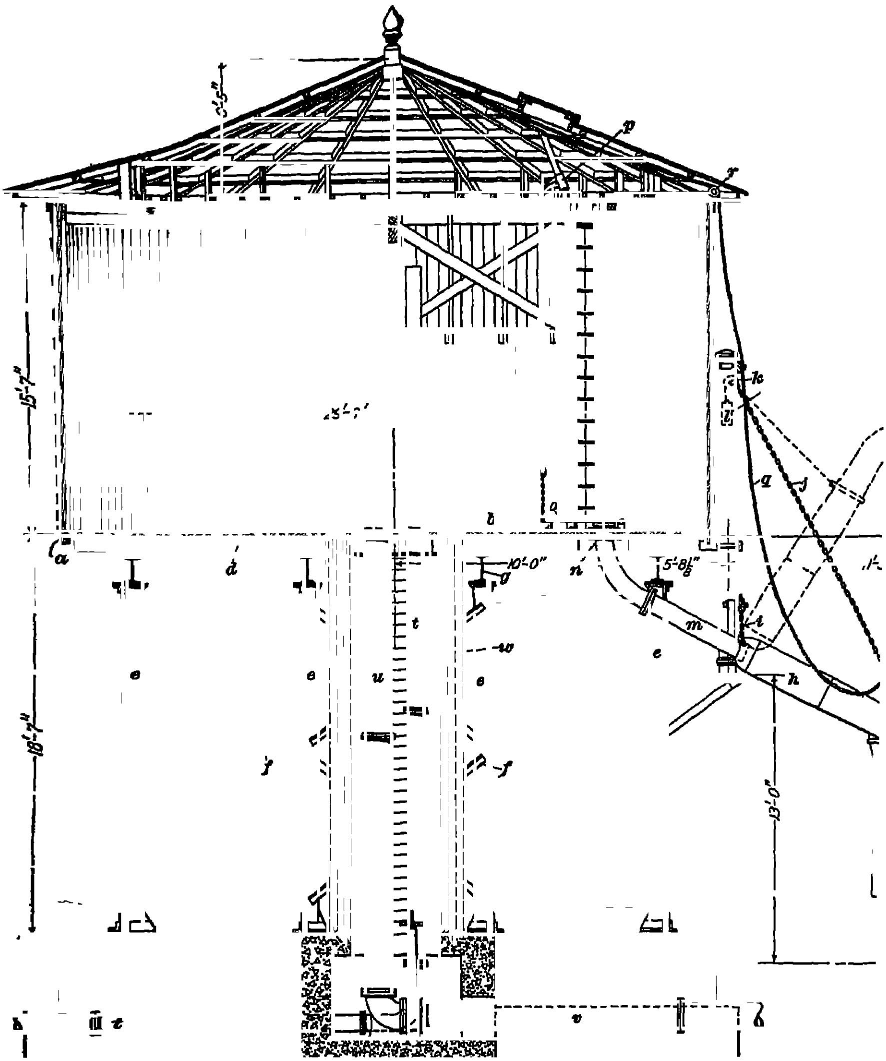
Where the hardness of water is due to sulphates of lime and magnesia, the treatment consists of adding carbonate of soda and hydrate of soda, either alone or together. Where the water contains carbonic acid and sulphates of lime and magnesia, it is customary to add sufficient soda to decompose the sulphates of lime and magnesia, and as much lime as is required to absorb the carbonic acid Where the water contains bicarbonates of lime and magnesia, a lime solution is added The strength of the solution to be added depends upon the chemical composition of the water, which varies greatly In any case, the water is allowed to stand undisturbed while the chemical changes take place and the objectionable elements settle to the bottom Water overflowing from the settling tank is pumped to the water-supply tank.

56. Pumping.—Since the source of supply is generally too low for the water to flow directly to the elevated tanks from which locomotives are supplied by gravity flow, resort is had to pumping. Steam, oil, or gasoline engines, or electric motors, may be used to operate the pumps, according to local conditions and the power available Steam boilers and pumps require the most attention, but in many cases steam is available from boilers at repair shops With electric operation, automatic control is practicable and economical, the motor being started automatically when the water reaches a certain low limit in the supply tank and then stopped automatically when the water reaches its upper limit Windmill pumps have been used to some extent, particularly on the plains where steady winds prevail, but it is necessary to provide ample storage capacity to insure against periods of calm.

57. Water Tanks.—The elevated supply tank is usually placed close to the track and has a hinged spout that can be lowered to the manhole of the locomotive tender It may also be placed a short distance from the track, in which case it has an underground main leading to a *water column*, which will be described later, from which the water is delivered to the locomotive. These supply tanks are constructed of wood, steel, or reinforced concrete, and have capacities ranging from 50,000 to 200,000 gallons An outside indicator operated by a float is used on all tanks and shows the water level in the tank, this level should not be allowed to go below 5 feet in order to provide for an emergency

58. Wooden Tanks.—Wooden tanks are commonly made of cypress, cedar, redwood, or white pine They are 24 to 30 feet in diameter, 16 to 20 feet high, and have capacities of 50,000 to 100,000 gallons The tank consists of vertical staves and a plank bottom, the staves being bound together by hoops of wrought iron or steel These hoops are either flat bands or round rods Each stave is 6 to 8 inches wide, $2\frac{3}{4}$ to 3 inches thick at the edges, and is grooved near one end to receive the bottom planks The outer side of each stave should be surfaced to the true circle of the tank and the edges accurately planed or sawed radially so as to make tight joints when put together The planks for the bottom are 8 to 12 inches wide and 3 inches thick, and each plank has a 3-inch chamfer or bevel at the ends to fit the grooves in the staves. Planks for tanks 24 feet in diameter should be in one piece, but those over 24 feet in length may be spliced

A wood-stave tank of 76,000 gallons capacity, bound with flat hoops and mounted on a steel tower, is shown in Fig 31, in cross-section in (*a*) and in elevation in (*b*) The staves *a* of the tank are 6 inches wide, 3 inches thick, and 16 feet long Near the bottom they are grooved, as shown in (*a*), to receive the planks forming the tank bottom *b* On the ends of each hoop are riveted lugs *c* in (*b*), and a horizontal bolt is put through these lugs to draw the hoop tight The spacing of the hoops is widest at the top and decreases toward



(a)

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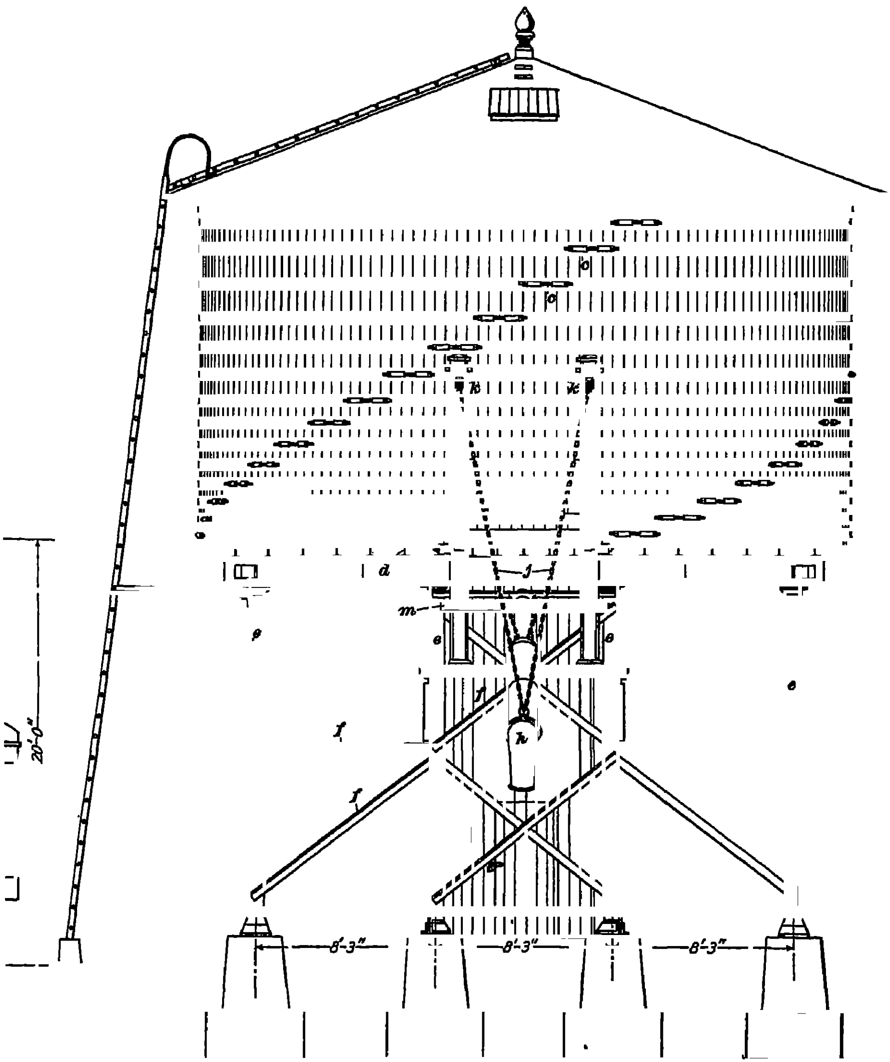


(b)

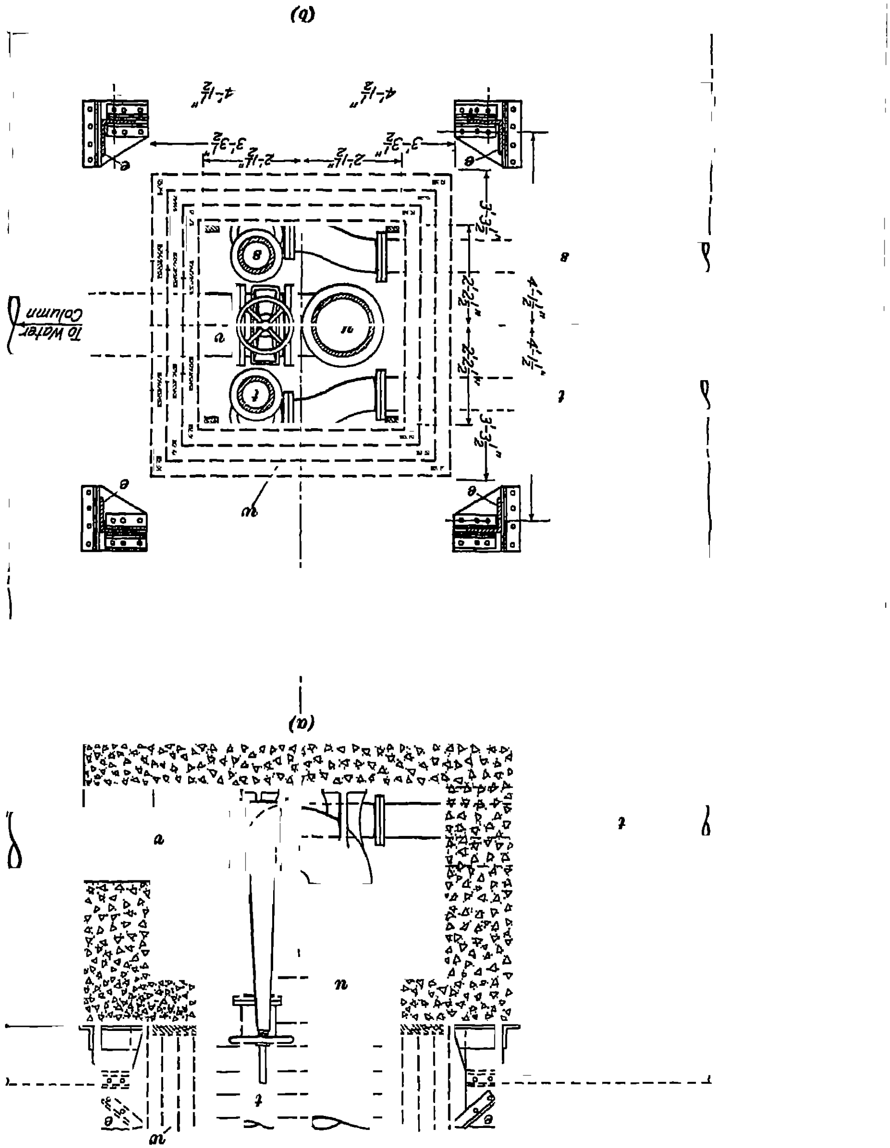


FIG 32

the bottom, where the bursting pressure of the water is greatest. It should be noted that the staves do not rest on the tower but that the tank bottom is placed directly on the steel I-beam joists *d*; hence, no upward pressure comes on the staves. Details of the piping system, which will be described later, are shown in Fig 32 in elevation in (*a*) and in plan in (*b*).

59. Steel Tanks.—Steel tanks are built up of structural-steel plates riveted together They usually have either conical, hemispherical, or elliptical bottoms and are supported on steel towers riveted to the plates

An example of a conical-bottom, steel tank is shown in Fig. 33 The circular steel plates *a*, forming the side walls of the tank, are securely riveted together and to the bottom *b* The riser *c*, riveted to the bottom, acts as a settling basin for any sediment or foreign matter in the water The float gauge *d* indicates the water level in the tank, and the revolving ladder *e* permits ready inspection of the tank at any point

60. Tank Towers.—Flat-bottom tanks are supported on towers that carry the tank bottom at a height of 20 to 30 feet above the rails Wooden towers are composed of wood posts, resting on stone or concrete pedestals, and tied together with diagonal braces of planks and horizontal tie-rods In the steel tower of Fig 31, the posts *e* are 6″×6″ angles, they are laced with 3″×3″ angles *f* The posts carry caps *g* of 15-inch I-beams, across which are laid the 8-inch I-beam joists *d*

The tower supporting the steel tank in Fig 33 consists of latticed steel columns *f*, anchored to concrete pedestals, and tied together by steel rods *g* Additional support is gained by the large riser *c* riveted to the bottom of the tank.

61. Tank Spouts.—The usual type of discharge spout for supplying the locomotives with water is shown in Fig 31 at *h* The heel of this spout is suspended by short chains *i* To the end of the spout are attached two chains *j*, spreading apart like a **V** and passing over pulleys *k* to counterweights *l*

When the spout is raised by means of the chains *j* and is not in use, it will stand clear of the tank pipe *m*, as shown dotted, and will thus drain itself. Any leakage from the pipe *m* will also fall to the ground and not accumulate or freeze in the

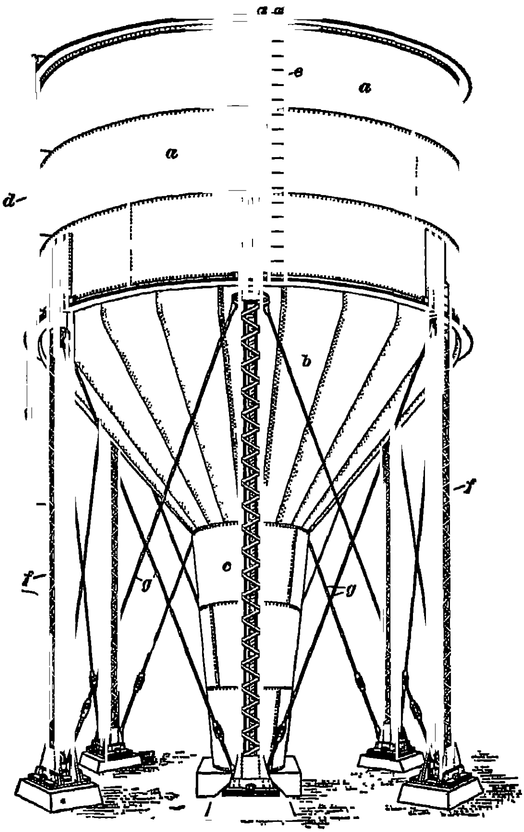


FIG 33

spout On the tank end of pipe *m* is a flat valve *n* with lever *o* connected by chain and rod to a lever *p* located near the top of the tank A rope *q* attached to the lever *p* passes over a pulley *r* and hangs within reach of the fireman on the locomotive tender, by pulling this rope the fireman opens the valve *n* and allows the water to flow into the tender tank

62. Tank Piping.—The piping system used with a water tank is shown in elevation in Figs 31 (*a*) and 32 (*a*), and in plan in Fig 32 (*b*) An 8-inch inlet pipe *s* and an 8-inch overflow pipe *t*, both of cast iron, extend up to the tank bottom and are continued to suitable heights inside the tank by 8-inch wrought-iron pipes bolted to their flanges There is also a 14-inch pipe *u* connecting with a main *v* leading underground to a water column The pipes are enclosed in a frost-proof box *w* built up of horizontal layers of planks and tarred paper, with air spaces between the layers and with an outside sheathing of beaded plank placed vertically. If a pump house or shop building is near at hand, steam can be piped into the frost box. In cold northern climates, the entire structure of tower and tank is sometimes enclosed by timber sheathing The base of the tower may then be used as a pump room, and fitted with a stove in winter

In the tank in Fig 33, all the necessary piping is contained in the large riser *c* To protect the pipes from frost, the entire outside surface of the riser may be covered and a stove heater placed in a chamber in the bottom of the riser.

63. Water Columns.—At terminals and yards, water is usually delivered to locomotives by water columns located at convenient points alongside or between the tracks A water column, Fig 34, consists of a vertical pipe *a*, 10 to 12 inches in diameter, and a horizontal branch or spout *b* The pipe *a* is made so that it can be rotated in its base *c*, the lever *d* being used for that purpose The spout normally stands parallel with the tracks When a locomotive is to take water, the pipe is swung around so that the spout extends across the tender, and a flexible ball-and-socket joint *e* allows it to be pulled down, as shown in the dotted position *f*, to discharge water into the manhole of the tender tank

When the spout is in this position the fireman standing on the tender pulls the lever *g*, raising the main valve *h* in the pipe pit, and thus admits water from the underground main *i* connected to an elevated supply tank In the illustration the valve *h* is shown open When the tender is full,

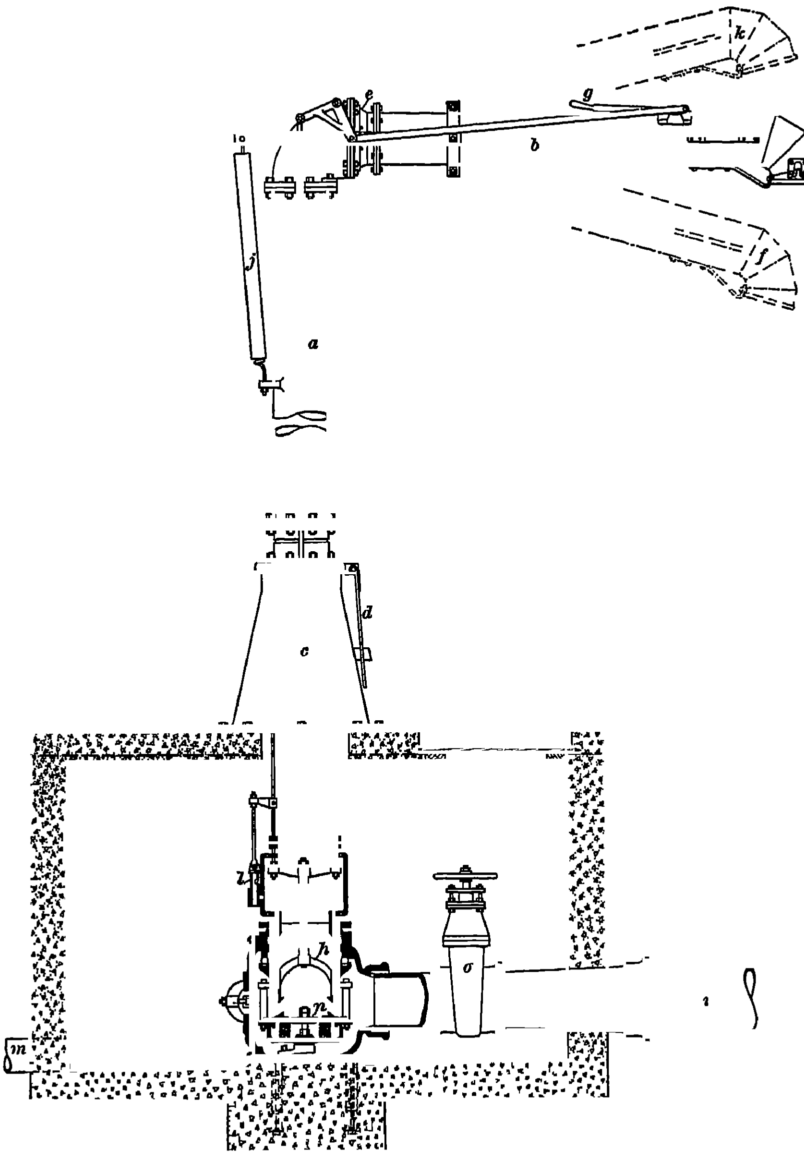


Fig 34

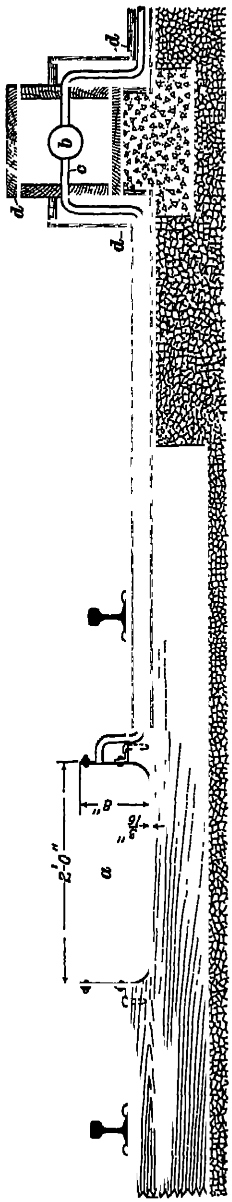


Fig 35

the valve is closed by means of the lever *g*, and the column is swung around clear of the tracks, the spring *j* then raises the spout a little above the horizontal, to the dotted position *k*, so that the water left in the spout will drain back into the pipe *a* As the main valve closes, a small valve *l* opens a hole, allowing the water left in *a* to flow out into the pit, which has a drain or sewer connection *m* Since the main valve is subject to rough treatment, it is made to close against a plate *n*, carried on spiral springs in the bottom of the valve chamber, so that if the valve is slammed down hard the shock is absorbed by the springs In some designs a screw and hand-wheel are used instead of the lever *g*, so that the valve closes slowly and without shock The supply main *i* is usually somewhat larger than the column pipe *a* A gate valve *o* on the supply main provides for shutting off the water to permit repairs to the water column.

64. Track Tanks.—Where the traffic is heavy and fast passenger trains make long runs without stopping, track tanks are provided to enable the locomotives to take water while running 20 to 40 miles an hour The tank is a steel trough, 6 to 8 inches deep and 20 to 24 inches wide, laid along the middle of the ties on a level stretch of road for a distance of 1,200 to 2,000 feet It is held in

position by spikes but is free to move longitudinally with expansion and contraction.

A typical track tank with pipe connections is shown in Fig 35 The tank *a* is 24 inches wide and 8 inches deep, and is made of $\frac{3}{16}$-inch metal The track is well ballasted with stone to drain away the water that is splashed out; in some cases, tile drains are laid and the ballast is covered with stone slabs to prevent its being washed out of place Water is supplied to the track tank from an elevated tank by means of a main pipe *b* laid along the track and small branch pipes *c* entering the trough at intervals. These pipes are encased in plank boxes *d*. In winter, the water in the trough is warmed by steam jets from perforated pipes, placed about 40 feet apart along the entire length of the tank and connected to a boiler at the pumping station The pumps may also keep the water in circulation as an additional precaution against freezing Steam pipes are sometimes laid along the ties and near the rails to prevent the water splashed out of the tank from freezing on the rails

65. Application of Track Tank.—A locomotive that takes water from a track tank must have the tender tank fitted with a vertical pipe projecting through the bottom; this pipe has a double elbow on its upper end, to discharge downwards into the tank, and a flexible spout or scoop hinged to its lower end The scoop is fitted with a chain so that it can be raised or lowered When the locomotive passes over the tank, the fireman lowers the scoop about 3 inches into the water. The speed of the locomotive forces the water up through the pipe into the tender tank. With a travel of 1,500 feet, about 5,000 gallons of water may be taken Signs or signals are placed at the approach end of the tank and within 100 feet of the far end to indicate where the scoop should be lowered and raised.

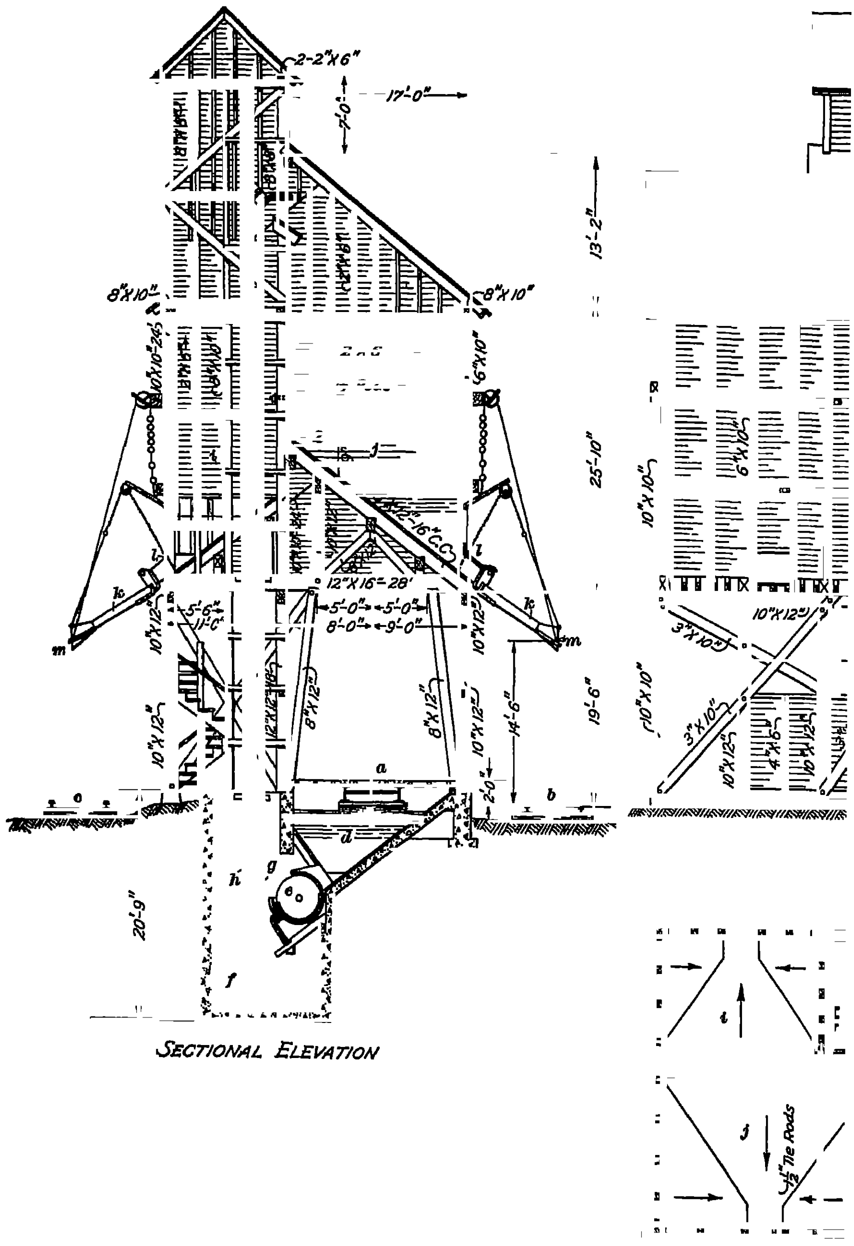
FUEL STATIONS

66. General Discussion.—Facilities for supplying fuel to the locomotives are provided at division points, terminals, and other points along the line, so that locomotives may take

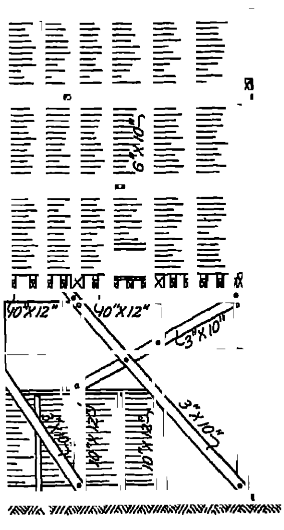
fuel before and during their trips These stations are usually located at the same points as water stations, enabling the locomotive to take fuel and water at one time On roads operated by locomotives burning coal, it is the general practice to store the coal in elevated pockets or bins, from which hinged inclined spouts are lowered to deliver it to the locomotive tenders. Usually the coaling station is at the side of, or between, the tracks, but sometimes one or more tracks pass under the bins If a large number of parallel tracks are to be served, the bins may even be placed on a bridge spanning the tracks On oil burning roads, the locomotives receive their supply of oil from oil columns, which are similar to the water columns already described The oil is pumped from a storage tank either directly to the oil column or to an elevated tank, giving a gravity flow through a main leading to the oil column, as explained later A locomotive tender holds from 10 to 20 tons of coal or from 3,000 to 5,000 gallons of fuel oil In freight service, a locomotive consumes from 4,000 to 5,000 pounds of coal per hour, and in passenger service from 6,000 to 7,000 pounds per hour

67. Car-Incline Coaling Station.—A car-incline coaling station is used in open country, where there is plenty of room. The coal bins are filled by dumping or shoveling coal from cars on a track above them, and the locomotive tender is served from these bins. An inclined track supported by a timber or steel trestle usually leads from the ground level to the top of the bins, and the coal cars are hauled up this incline by a cable and steam or gasoline hoist They may be pushed up by a locomotive, empty cars being placed between the coal cars and the locomotive so that the locomotive does not have to ascend the incline The grade of the encline should not exceed 5 per cent if locomotives are to work on it, but if a haulage cable is used this grade may be as great as 20 per cent

68. Mechanical Coaling Stations.—Mechanically operated coaling stations are extensively used and represent modern practice. In this type of coaling station, the coal is



SECTIONAL ELEVATION



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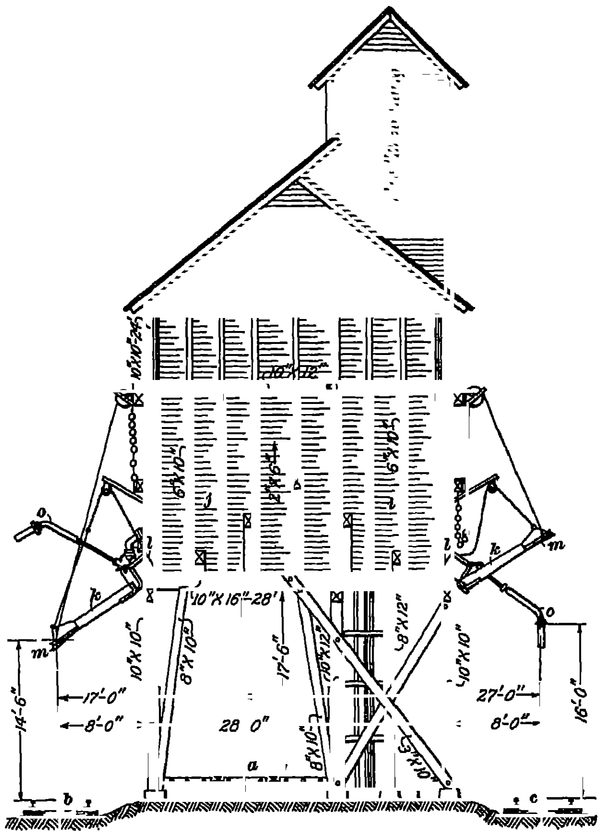
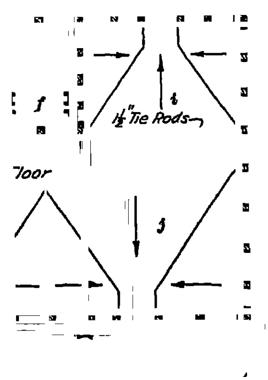


END ELEVATION



'loor

dumped from cars on a surface track into a hopper beneath the track, and is then fed to an elevator bucket or a conveyor working in a tower and discharging the coal into elevated bins If the elevator is worked by an electric motor, its operation is largely automatic, it is started by pressing any one of two or three push buttons, located in convenient places about the station, and it continues to operate steadily until stopped in the same way If the operator, when at the top of the plant, finds that coal is needed in an elevated bin, he presses one of the push buttons and thus starts the supply without descending to the ground. One elevator equipped with forked chutes fitted with gates can serve two or more bins This is particularly convenient where the station has to supply different grades of coal for locomotives fired by hand and those equipped with mechanical stokers Mechanical coaling stations are built with bins of 50 to several hundred tons capacity There are numerous variations in the design of such stations and the construction may be of timber, reinforced concrete, or steel The elevator or conveyor machinery may be driven by a steam, oil, or gasoline engine, or by an electric motor.

69. Timber Coaling Station.—An example of a mechanical coaling station constructed mainly of timber is shown in Fig. 36 The station is built over the coal supply track *a* and serves locomotives on the two outside tracks *b* and *c*. Coal dumped into the track hopper *d* from cars on track *a* is fed intermittently by the revolving loader or feeder *e* into elevator buckets traveling in the elevator shafts *f* along the guides *g* and *h* At the top of the shafts the guides *g* are curved so as to tilt the buckets and discharge the coal into the bin, which is provided with two hoppers *i* and three hoppers *j*, having inclined bottoms, as shown The arrows in the plan indicate the directions in which the bottoms of the hoppers slope downwards The bin has a capacity of 600 tons and is equipped with five spouts *k* for delivering the coal to the locomotives These spouts are rectangular in cross-section and are hinged and counterweighted so that they

can be raised to a vertical position out of the way when not in use When a spout is pulled down to the locomotive tender, a gate *l* is raised, allowing the coal to run through the spout and into the tender When the spout is raised, the gate descends and cuts off the flow of coal The discharge end of each spout is fitted with a head *m*, which is open only at the bottom so that the coal drops vertically into the tender and spilling is avoided To prevent a confusion of lines in Fig 32 all spouts have been omitted in the plan and front elevation

The coal supply track is usually constructed with a slight slope upwards from the main track level, loaded cars can thus be set at the upper end of the track and moved by gravity down to the track hopper as required A bar screen covers the hopper and retains any large lumps of coal, which must then be broken into smaller pieces so that they will fall through

70. Reinforced-Concrete Coaling Station.—A coaling station constructed mainly of reinforced concrete is shown in Fig 37, in elevation in (*a*), plan in (*b*), and sections in (*c*) and (*d*) In this design the coal car enters on the coal-supply track *a*, the coal is dumped into the track hopper *b* and served to a 2½-ton elevator bucket *c*, operating in the elevator tower *d* As shown in (*b*), there are two elevator towers, *d* for coal and *e* for ashes The one shown in elevation in (*a*) is the elevator tower *e*, which will be discussed later The bucket of coal is automatically lifted to the top of the tower *d*, to the position shown dotted in (*a*), and is emptied through a coal chute *f* into a tram car *g* This tram car runs back and forth on a track *h* over the coal bins *i*, which it serves The tram-car track is located in the head house *j* built over the coal bins and extending to the towers Each bin has a capacity of 150 tons and is equipped with the usual coal spouts *k* in (*b*) and (*c*) for serving locomotives As soon as the elevator bucket delivers its load to the tram car, it is automatically released and descends to the bottom of the tower for a second load, the operations continuing intermittently as long as there is coal in the track hopper

Likewise, the tram car after emptying the coal into the bins returns to the chute *f* for a second load A locomotive requiring coal enters on any one of the four service tracks *2, 3, 4,* or *5* and receives its coal from a coal spout operated by a man on the operator's platform *l*, by means of the hand chains *m* and *n*, shown in (*c*)

71. Fuel-Oil Station.—At a fuel-oil station, tank cars of oil are placed on a track having a depressed pit or long trough between the rails, from which the oil flows to underground storage tanks, or the track may be elevated on a trestle so that the oil will flow to surface tanks To supply the engines the oil is pumped to an elevated tank alongside the tracks. Elevated tanks for oil are similar to water tanks and have a capacity of from 20,000 to 100,000 gallons They should be placed high enough to give a height or head of about 12 feet above the oil column, to which the oil flows by gravity To avoid waste and dirt from dripping oil, the spout of an oil column is arranged to stand vertically or inclined upwards when not in use, so that any oil in it will drain back into the main pipe of the column

MISCELLANEOUS YARD AND TERMINAL STRUCTURES

72. Sand Plants.—Sand is carried by all locomotives to be dropped on the rails when they are greasy or wet, so as to make the driving wheels grip the rails in starting or when brakes are applied in stopping It is essential that the sand should be dry so that it will flow freely and will not pack or stick in the sandboxes or in the pipes through which it is distributed to the rails

A fuel station usually has facilities for replenishing the sand boxes of a locomotive The dry sand is generally stored in compartments built in the coal bins or in separate sand boxes supported on towers between tracks In Fig. 36 the dry sand is stored in the compartment *n*, shown in plan, which is fitted with sand spouts *o*, in the end elevation, for delivering the dry sand to the locomotives on tracks *b* and *c*.

In the coaling station illustrated in Fig. 37, the wet or fresh sand enters on the sand-supply track *o* and is stored in the sand house *p* As shown in (*d*), the track *o* is supported by steel girders resting on concrete piers. At one end of the sand house are located the devices for drying the sand. The wet sand is shoveled from the storage pile into hopper *q* and is raised by the elevator *r* to the chute *s*; from there it flows down over and around the drying stoves *t*, and when dry it drops on the screen *u* that excludes stones, pebbles, or lumps After passing through the screen, the dry sand drops into the hopper *v* and is taken by the elevator *w* to the top of the elevator tower where it passes through a chute *x* and is delivered to a belt conveyer *y* that carries it to the sand bins *z* Each of these sand bins has a capacity of 465 cubic feet and is fitted with sand spouts *a'* for delivering the sand to the locomotives.

73. Ash-Pits.—The numerous kinds of ash-pits in use may be divided into two classes; namely, depressed-track pits, and mechanically operated pits In the former class, the locomotive track is over a pit the floor of which slopes slightly toward a depressed track on which ash cars are operated This depressed track is approached by an incline and is at such an elevation that the tops of the ash cars are about level with the edge of the pit floor on each side To clear a locomotive of its ashes, the locomotive is run over the ash-pit and the ashes are dropped and raked from the grates and ash-pans into the pit The ashes are then cooled with water, are shoveled by hand into the ash cars, and hauled away. The floor and walls of the ash-pit should be faced with firebrick or vitrified brick so as not to be damaged by the hot ashes

74. Mechanical handling of ashes is desirable where more than twenty locomotives have to be cleaned in 24 hours A few of the many types of mechanically operated ash-pits are as follows

1. Water pits, illustrated in Fig 38, are much like the depressed-track pits, but they have sloping sides and have

closed ends to hold the water. The hot ashes fall into the water in the ash-pits *a*, are cooled, and then removed to the ash cars *b* by the grab bucket *c*. This bucket is handled by a hoist *d* operating back and forth on the traveling bridge *e* spanning the locomotive tracks *f*, ash-pit *a* and ash-car track *g* In many cases the grab bucket is handled by a locomotive crane traveling on a track alongside the ash-pit The rails of track *g* and the inner rails of track *f* are carried on girders supported by piers along the middle and sides of the ash-pit *a*

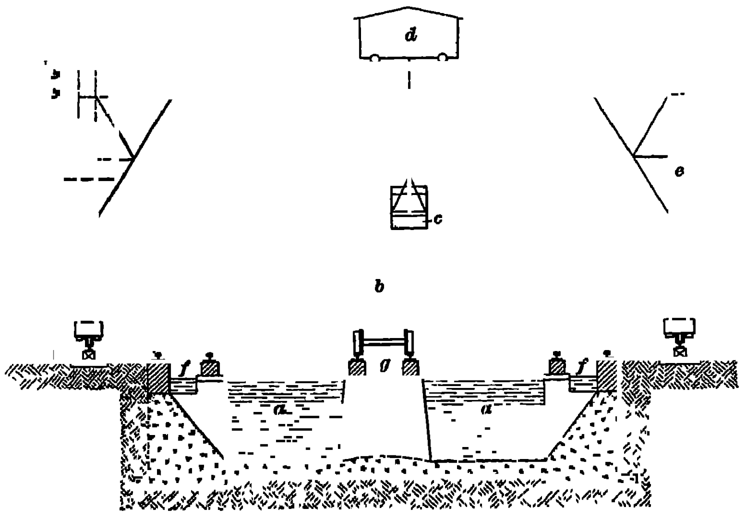


FIG. 38

2 Pits with small iron cars that are hauled out by cable on an incline at right angles to the locomotive track, and dumped into railway cars standing on an adjacent ash track

3 Pits fitted with stationary buckets that are removed by a locomotive crane or gantry crane and dumped into ash cars or an ash bin

4 Pits with iron cars that receive the ashes and then travel along a track in the pit to discharge into a hoist or conveyer at the end

5 Pits in the form of a hopper in the track and serving a tram car or conveyer operating on rails in a tunnel cross-

ing under the locomotive tracks, and discharging into an elevator bucket at the end

An illustration of the last mentioned type of ash handling plant is shown in connection with the coaling station of Fig 37 This plant has four ash-pits *b'*, lined with firebrick and each having a capacity of 225 cubic feet A tram car *c'* receives ashes from any pit, runs along the overhead rails *d'* in the tunnel *e'* and dumps its load into the elevator bucket *f'* This bucket is then elevated to the top of the ash tower *e* and the ashes are emptied through the spout *g'* into the ash bin *h'* From the ash bin the ashes are dumped into empty coal cars, standing on track *a*, and are hauled away

75. Track Scales.—The weight of freight shipped in carload lots is determined by deducting the weight of the empty car, which is marked on the car, from the weight of the loaded car To weigh the loaded car, it is passed over a track scale of 100 to 150 tons capacity The track scale usually consists of a platform supported on weighing beams that are connected to graduated scale beams The weighing beams are located in a pit between the rails This pit has concrete, brick or stone walls and a concrete floor, and is covered by a platform, which is 50 to 60 feet long The graduated scale beams are usually in a building adjacent to the platform The weights are read in this building and may be recorded automatically

Where cars are to be weighed in motion, as in passing over a track scale on the descending side of a switching hump, the grade on the scale should not exceed 1 per cent The accelerating grade above the scale should be such that the speed of cars will not exceed 4 miles per hour so that each car will be alone on the scale for at least 3 seconds. In a yard arranged for flat switching, the track scale may be on a special track Cars to be weighed may then be pushed slowly along this track and over the scale by a locomotive

76. Cranes.—Every freight yard should be equipped with some sort of crane for transferring bulky or heavy pieces of freight to and from vehicles and cars At small

stations a simple jib crane may be used A convenient form of crane for large stations is one mounted on a traveler operating back and forth along a fixed runway at right angles to the tracks In operating, the crane picks up its load, moves along the runway and places the load in either the freight car or the vehicles This type of crane can also be arranged to travel on rails located adjacent to the tracks, thus permitting the crane to move not only laterally to the tracks, but also parallel with them

77. Oil Houses.—The various kinds of oil used on railroads, such as cylinder oil, signal oil, valve oil, etc, should be stored in tanks located in a pit or basement under the

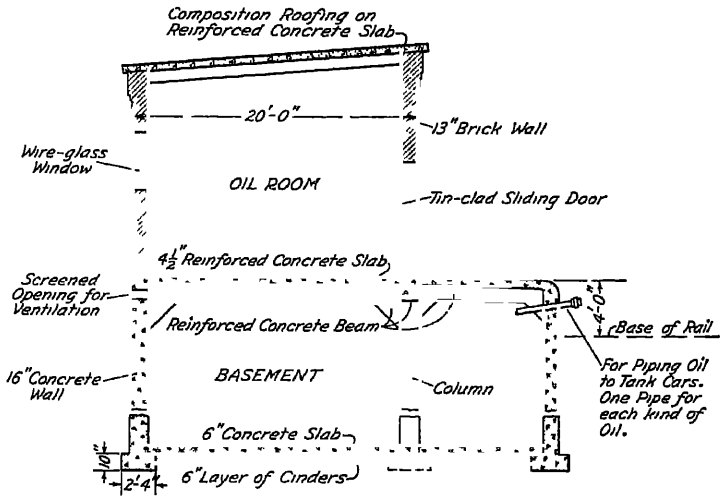


FIG 39

oil house If a sufficient quantity of any one kind of oil is used, it is delivered to the storage tanks directly from the tank cars Oils that are stored only in small quantities are delivered to the oil house in barrels and are run into tanks through pipes in the floor

In Fig 39 is shown a cross-section of a typical oil house recommended by the American Railway Engineering Association This building is 20 feet wide, 40 feet long, and

is constructed of reinforced concrete and brick The necessary openings are protected by tin-clad doors and wire-glass windows to make the structure fireproof The height of the basement is governed by the number and size of storage tanks used In the oil room are located the pumps and automatic measuring faucets for delivering the various kinds of oil. Such a building should be heated by steam and lighted by electricity A fireproof trap door should be the only opening into the basement besides the necessary opening for pipes